

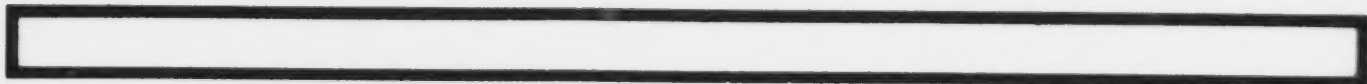
Performance Characteristics of
Package Water Treatment Plants

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PERFORMANCE CHARACTERISTICS OF
PACKAGE WATER TREATMENT PLANTS

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Cooperative Agreement No. CR806449

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16. ABSTRACT This study was undertaken to collect reliable on-site information on the quality of treated water produced by package plants. Six plants in operation year around were selected to be representative of those serving small populations and were monitored to assess their performance. Plants selected used surface water sources. Sampling trips were made over a 2 year period. At each plant, samples were collected of the raw water, the treated water, and water from the distribution system. Turbidity, total coliform, and chlorine residual data were collected on all visits. Standard plate counts, chemicals listed in the USEPA Drinking Water Regulations, and trihalomethanes were determined intermittently. Only one treated water sample, a distribution sample, showed any total coliforms. Sixty-eight percent of the treated water standard plate counts showed densities of 10 or less per milliliter. Three of the plants met the 1 ntu turbidity standard on nearly all occasions. The other three plants were meeting the standard during less than half of the sampling trips. Failure of these plants to perform well is attributed to the variability and quality of their sources and/or to the lack of skilled operators having sufficient time to devote to treatment.		
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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollution discharges from municipal and community sources, to preserve and treat public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, and provides a most vital communication link between the researcher and the user community.

Many small communities in this country use prefabricated package water treatment plants to treat surface waters to supply their drinking water. Six plants were monitored intermittently over a period of 2 years to establish their effectiveness in removing turbidity and bacteria.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

This study was undertaken to collect reliable onsite information on the quality of treated water produced by package plants.

Information concerning package plant installations in the U.S. was sought via a questionnaire. Over five hundred installations supplying potable water were identified through lists obtained from manufacturers and state agencies. This total is not inclusive of all such plants as not all manufacturers or states supplied lists of installations.

Six plants in operation year-around were selected to be representative of those serving small populations and were monitored to assess their performance and ability to supply water meeting the National Interim Primary Drinking Water Regulations. All plants selected used surface water sources.

Site visits were made over a 2 year period. At each plant, grab samples were collected of the raw water, treated water, and water from the distribution system. Turbidity, total coliform, and chlorine residual data were collected on all visits. Standard plate counts, chemicals listed in the USEPA Drinking Water Regulations, and trihalomethanes were determined intermittently.

Only one treated water sample, a distribution sample, showed any coliforms. Sixty-eight percent of the treated water standard plate counts showed densities of 10 or less per milliliter.

Three of the plants met the 1 ntu turbidity standard on nearly all occasions. The other three plants were meeting the standard during less than half of the sampling trips. Failure of these plants to perform well is attributed to the variability and quality of their sources and/or to the lack of skilled operators having sufficient time to devote to treatment.

This report was submitted in fulfillment of Cooperative Agreement CR806449 by the University of Cincinnati under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period December, 1978 to June, 1981 and work was completed as of October 17, 1981.

CONTENTS

Foreword	iii
Abstract	iv
Figures	vi
Tables	vii
Acknowledgments	ix
1. Introduction	1
2. Conclusions	2
3. Background	4
Small Systems	4
Regulations	5
Prevalence.	9
4. Design.	11
Unit Operations	11
Manufacturers	15
5. Procedures.	20
Field Procedures.	20
Analytical Methods.	24
6. Case Studies.	27
Site W	29
Site T	35
Site V	41
Site R	50
Site P	58
Site C	58
7. Summary	70
References	72

FIGURES

<u>Number</u>		<u>Page</u>
1	Number of potable water supply package plants identified in the U.S.	10
2	Site W facility layout	30
3	Site W Neptune Microfloc AQ40	31
4	Site T facility layout	36
5	Site T Neptune Microfloc AQ40	37
6	Site V facility layout	42
7	Site V Neptune Microfloc AQ40	43
8	Site V Turbidity Removal	47
9	Site R facility layout	51
10	Site R Neptune Microfloc AQ12	52
11	Site P facility layout	59
12	Site P Neptune Microfloc WB133	60
13	Site C facility layout	64
14	Site C Permutit 200 GPM	65

TABLES

<u>Number</u>		<u>Page</u>
1	Water treatment design standards	6
2	Solids contact unit design standards	8
3	Facilities in study	22
4	Schedule of field trips	23
5	Analytical methods	25
6	Treatment process characteristics	28
7	Site W microbiological analysis and water quality characteristics	32
8	Site W trihalomethane analysis	33
9	Site W chemical analyses performed by USEPA	34
10	Site T microbiological analysis and water quality characteristics	38
11	Site T trihalomethane analysis	39
12	Site T chemical analyses performed by USEPA	40
13	Site V microbiological analysis and water quality characteristics	44
14	Site V trihalomethane analysis	48
15	Site V chemical analyses performed by USEPA	49
16	Site R microbiological analysis and water quality characteristics	53
17	Site R trihalomethane analysis	56
18	Site R chemical analyses performed by USEPA	57
19	Site P microbiological analysis and water quality characteristics	61

<u>Number</u>		<u>Page</u>
20	Site P trihalomethane analysis	62
21	Site P chemical analyses performed by USEPA	63
22	Site C microbiological analysis and water quality characteristics	67
23	Site C trihalomethane analysis	68
24	Site C chemical analyses performed by USEPA	69

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SECTION 1

INTRODUCTION

The problem of providing acceptable water supplies to the public is particularly acute for small communities with limited financial resources and limited availability of competent treatment plant operators. Recreational areas in isolated locations also must provide acceptable drinking water to their visitors and staff while confronted with the difficulty of attracting personnel with experience and skill in water treatment. During the last 20 years, cost savings have been achieved in such situations by using package water treatment plants. A package plant generally consists of prefabricated and largely preassembled clarification and filtration units. These plants are reputed to require minimal operational skill and to be a viable and economical low-flow alternative to the custom-built facility. Six such plants serving small populations were selected for study. These plants were monitored to assess their performance and ability to supply water meeting the National Interim Primary Drinking Water Regulations, particularly the turbidity and microbiological requirements.

The design of a custom-built treatment plant should depend on an evaluation of the nature and quality of the particular water to be treated. Package plants are designed with the goal of producing a satisfactory quality of treated water from a range of influent waters. Flow rates for plants on the market range from 10 to 2100 gpm.

The financial and personnel limitations faced by small communities and recreational areas can be alleviated by prefabricated plants of this type. The question of the adequacy of treatment provided by these plants as they are managed and operated by small communities and recreational areas is not answered by data available in the literature. This study was undertaken to collect reliable onsite information on the quality of treated water produced by package plants.

SECTION 2

CONCLUSIONS

The package plant at Site V reduced the turbidities of more than 100 ntu of the source water to less than 1.0 ntu. On one occasion, the influent turbidity increased from 17 ntu to greater than 100 ntu within a 2 hour period while the effluent turbidity remained less than 1.0 ntu. On earlier occasions, prior to the performance of adequate maintenance, this plant did not consistently reduce the turbidities of the influent level in the range of 35 - 50 ntu to an acceptable level.

At Site R influent turbidities greatly in excess of 500 ntu were encountered and not successfully treated. Moreover, even with influent turbidities of less than 30 ntu, the plant was not able to achieve an effluent turbidity of less than 1 ntu because of inadequate operator skill.

The maximum influent turbidity recorded at Site P was 17.2 ntu during this study. Of 9 effluent samples measured at this plant, only 3 were less than 1.0 ntu. This plant was in operation an average of 13.7 hours per day and the operator was present no more than 2 hours per day.

The source waters at plant Sites C and W had turbidities of less than 30 ntu. Operators at these locations were experienced and effluent turbidities measured exceeded 1.0 ntu only once during this study.

The maximum influent turbidity measured during this study at Site T was 10.4 ntu. A pump failure and a distribution system problem that required extensive operator attention caused effluent turbidities of 1.9 and 3.2 ntu respectively. Otherwise, the maximum effluent turbidity was 1.1 ntu.

These specific findings lead to the following general conclusions regarding applications of package plants.

Package water treatment plants manned by competent operators can readily treat the turbidity and bacteria of surface waters of fairly consistent quality. Reservoirs have proven satisfactory for providing acceptable influent waters.

Package plants using variable sources, e.g., streams, require a high degree of operational skill. A variable source necessitates near constant vigilance of the package plant by the operators.

Regardless of their source quality, package plants require a certain level of maintenance and operational skill. Lack of this minimal skill and attention precludes consistent successful turbidity removal irrespective of the influent quality.

Most package plants are located in rural or remote areas where it may be difficult to hire well trained operators. Small communities may have to greatly increase salaries to attract well qualified operators.

SECTION 3

BACKGROUND

SMALL SYSTEMS

Data available on the number of community water systems in the United States vary depending on their source. A committee report to the American Water Works Association indicates there are some 60,000 systems, of which more than 90 percent serve populations smaller than 5,000, and 95 percent serve less than 10,000 population (1). A U.S. Environmental Protection Agency draft briefing document presented to the National Drinking Water Advisory Council mentions some 59,000 systems, 87 percent of which serve populations under 2,500 (2). Most very small systems (populations under 500) are privately owned, and about half serve mobile home parks. The EPA compilation does not include Federal and Indian land systems. Approximately 1,000 of these are included in the AWWA report. (Although most community systems are small, the vast majority of the population is served by larger systems. The EPA document states that 79 percent of the 213 million persons protected by the Safe Drinking Water Act are served by large systems, i.e., systems serving more than 10,000 population.)

EPA estimates that 11,300 community systems are out of compliance for traditional contaminants in the Interim Primary Drinking Water Regulations. Of this number, about 5400 fail to meet inorganic standards, about 700 fall short of turbidity standards, and about 5200 do not meet bacteriological standards (including about 600 who also fail to comply with turbidity or inorganics).

The AWWA interim report lists problems and weaknesses of small- and medium-size water utilities as including, with various degrees of severity, lack of qualified operators, knowledge limitations, and finances. The lack of qualified operators is attributed to low salary, limitation in training opportunities, part-time positions, and limited upward mobility. The knowledge limitations include operating and maintenance procedures and selection of equipment and supplies.

Package water treatment plants are intended to alleviate some of these problems. A package plant has been defined for this report as a prefabricated, largely preassembled unit incorporating the conventional treatment process of flocculation, sedimentation, and filtration. There are commercially available treatment units employing other processes, such as ion exchange and reverse osmosis, for the removal of dissolved substances but these types of treatment were not included in the scope of this work.

The focus of this work is on the problems confronting small communities and recreational areas in providing safe drinking water to their customers.

This size and type of facility does not normally have the financial resources nor the access to skilled plant operators that might be found in a larger community or industry. Conventional treatment processes meet the lower cost and operational skill requirements that face small communities and recreational area operators.

Regulations

Information concerning regulations, restrictions or standards pertaining to package treatment plants in the U.S. and the locations of such plants was obtained by writing, during the winter of 1979, to the Health Department or other appropriate agency in each of the fifty states and Puerto Rico as well as to the Army Corps of Engineers. Replies were received from all except the states of Nevada, New Jersey, Oregon and Tennessee. Information concerning the locations of such plants was also obtained from the various manufacturers of water treatment package plants.

None of the states that replied to the written inquiry prohibit directly the use of prefabricated water treatment plants. Only a few have policies designed specifically for this type of plant. Many of the states follow the 'Recommended Standards for Water Works--Policies for the Review and Approval of Plans and Specifications for Public Water Supplies' (3) usually referred to as the 'Ten States Standards' established by the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers. The member states of the Board are: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania and Wisconsin. The following states are not members of the Board, but seem to have used the 'Ten States Standards' as a basis for their design standards: Arkansas, Louisiana, Maine, Massachusetts, Nebraska, North Dakota, South Dakota, Vermont, Washington, West Virginia and Wyoming. The 'Ten States Standards' are design oriented and do not directly address finished water quality.

The states of Alabama, Arizona, Georgia, Kansas, North Carolina, Oklahoma, Texas, Utah and Virginia have set up public water systems rules and regulations in a format similar to the 'Ten States Standards'. The specific design details differ somewhat and those of concern for conventional treatment are outlined for each of the nine above states in Table 1.

The water supply regulations of Colorado, Connecticut, Hawaii, Idaho, Mississippi, New Mexico and Rhode Island do not address plant design, but are written as water quality standards specifying maximum contaminant levels, analysis and sampling techniques, etc., that must be complied with. Of course, the public water supply in any state is subject to the conditions prescribed by the U.S. Environmental Protection Agency in the Safe Drinking Water Act and the National Interim Primary Drinking Water Regulations.

Prefabricated water treatment plants do not generally meet the design requirements given in the various states' regulations in the areas of detention times and filter rates. Design standards often are recommended standards and it is the policy of the 'Ten States' committee as well as many other states, 'to encourage rather than to obstruct the development of new processes and equipment.' Generally, approval for a new process may be given by a state

TABLE 1 WATER TREATMENT DESIGN STANDARDS (1978)

	10 States	ALA	ARIZ	GA	KAN	N CAR	OKLA	TEXAS	UTAH	VIR
RAPID MIX - detention (seconds)	>30	>60	30-120	-	30	-	30-120	60-120	>30	>10
FLOCCULATION - detention (minutes)	>30	>30	20-60	-	>30	>20	30-60	30-60	>30	>30
- flow vel. (fpm)	0.5-1.5	0.5-1.5	-	-	-	-	0.8-2.0	-	>0.5	-
- paddle vel. (fps)	0.5-2.0	0.5-2.0	0.5-2.0	-	-	-	-	-	0.5-2.0	-
- conduit vel. (fps)	0.5-1.5	<0.5	0.5-1.5	-	-	<0.5	0.5-1.0	-	0.5-1.5	<0.5
SEDIMENTATION - detention (hours)	>4 (1)	>4	>4 (1)	4	3-4 (2)	>4	>4	-	>4 (3)	>4
- overflow (gpd/sq ft)	-	<550	360-550 (4)	-	-	-	<600	-	-	360-550
- weir load (gpd/ft)	<20000	<20000	11500-28800	-	-	<20000	<20000	-	<50000	-
- flow vel. (fpm)	<0.5	<1	0.5-3.0	-	-	-	-	-	<3	<1
FILTRATION - rate (gpm/sq ft)	-	<4 (5)	-	2	5 (5)	4 (5)	2-3	<5	3-5 (5)	<4 (5)
- media depth (inches)	24-30	27-30	24-30	-	-	24-30	36-48	24-30	24-30	<27-30
- water depth (inches)	>36	>48	>36	-	-	-	-	-	>36	>36
- backwash (gpm/sq ft)	>15	15-20	>15	-	-	-	15-30	-	-	>15

- (1) may be reduced for lime-soda softening on ground waters
(2) depending on source, 1.5-2.0 hours where tube settlers allowed
(3) less where tube settlers used
(4) 550-1080 gpd/sq ft for lime softening
(5) for multimedia filters

if the process has been thoroughly tested as a pilot scale and/or a full scale plant for a period of time sufficient to indicate satisfactory performance.

Some states do have mandatory design standards which may effectively prevent the use of certain types of package plants. An example is Georgia where no package unit submitted to the state as of the date of this survey had been able to meet the obligatory requirements of 4 hours detention time prior to filtration and a maximum filtration rate of 2 gpm per square foot. The only three prefabricated water treatment plants in Georgia in 1979 were at Army Corps of Engineers recreational sites.

Tube settlers and mixed media filtration have been used in some package plants. The 'Ten States Committee' states that sufficient experience is not yet available to establish design standards for tube settlers and that pilot or full scale studies may be required prior to approval. Three states - Utah, Kansas, and Arizona - have specific design guidelines for tube settlers. If mixed media filtration is used, several states will allow filter rates higher than the traditional 2 gpm/sq ft.

The 'Ten States Standards' and various individual states specify design standards for solids contact units. These are summarized in Table 2.

The 'Ten States Standards' and many of the other states' design standards consider solids contact clarifiers acceptable for combining softening and clarification where raw water characteristics are not variable and flow rates are uniform. In most cases if solids contact units are to be used as clarifiers without softening, specific approval of the reviewing authority is required.

No states that replied to the request for information had regulations concerning direct filtration. The 'Ten States Standards' policy statement regarding this method of treatment is as follows:

"Although direct filtration has been suggested as an alternate method of complete treatment, sufficient experience is not yet available to establish design standards.

Where the reviewing authority has determined that the direct filtration process may be applicable, an engineering report, which includes a historical summary of raw water quality data with special reference to fluctuations in quality, changing meteorological conditions, sources of contamination, etc., shall be submitted prior to a study proposal.

If the report is accepted, a study proposal shall be submitted including the format for conducting a pilot plant and/or full scale demonstration satisfactory to the reviewing authority. Studies shall particularly emphasize:

1. Correlations between raw water quality and upset raw water boundary conditions for the process with a determination of anticipated down time.

TABLE 2 SOLIDS CONTACT UNIT DESIGN STANDARDS

	10 States	ARIZ	N. CAR	OKLA	TEXAS	UTAH	VIR
floc times (minutes)	≥ 30	≥ 30		20			≥ 30
detention (hours)	$\frac{4^{(1)}}{4}$	$\frac{4^{(1)}}{4}$		$\geq 2^{(2)}$	≥ 2	$\geq 2^{(3)}$	$\geq 2^{(3)}$
weir load (gpm/ft)	$\leq 10^{(4)}$	$\leq 10^{(4)}$	≤ 7	$\leq 10^{(4)}$		$\leq 10^{(4)}$	
upflow rate (gpm/sq ft)	$\leq 1^{(5)}$	$\leq 1^{(5)}$	≤ 1	$\leq 1.25^{(6)}$		$\leq 1^{(7)}$	$\leq 1^{(5)}$

- (1) for surface water
use 1 hour for ground water
- (2) for clarification
> 1.5 hours for softening
- (3) for clarification
1 hour for softening
- (4) for clarifiers
20 gpm/ft for softeners
- (5) for clarifiers
 ≤ 1.75 gpm/sq ft for softeners
- (6) for clarification
< 2.2 gpm/sq ft for softening
- (7) for clarifiers
1.5-2.5 gpm/sq ft for softeners

2. A determination of the quality and/or operational parameters which serve as the best measure of treatment serve as the means of process control.
3. A determination of chemical feed rates under varying raw water quality conditions necessary to optimize finished water quality.
4. Alternate sources and/or modes of treatment to insure reliability of service 100 percent of the time."

It is not permissible to treat surface water with direct filtration package plants in Colorado and Kentucky since these states require complete treatment for a surface source.

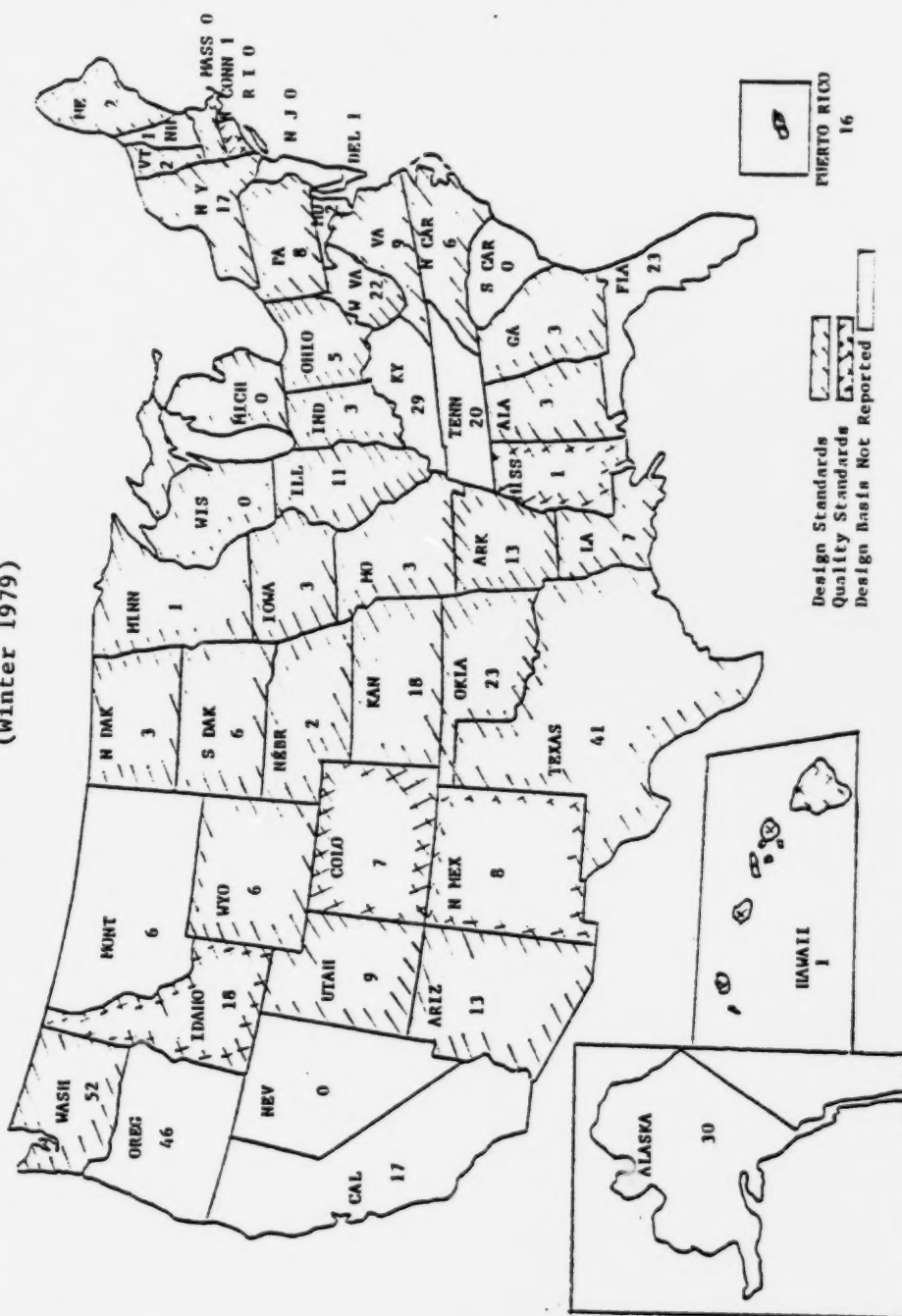
The majority of package plants are located in rural or remote areas. Many are in parks, campgrounds, and other recreational areas. These are also the areas where it may be most difficult to find well trained operators. Package water treatment plants are reputed to require considerably less operator attention than conventional facilities although they cannot be merely installed and then left to run by themselves. Of the forty-five states that responded to the request for information, nineteen did so with a copy of their water works or water supply regulations. Of these nineteen sets of regulations, only seven contained a clause dealing with state operator certification.

PREVALENCE

The number of package plant installations identified from the responses received from the individual states and from the manufacturers is compiled in Figure 1. The list totals 518 and is not complete since not all of the states and manufacturers contacted, nor the Corps of Engineers, had a list of their installations available to send.

The package plant sites are widely distributed across the U.S. with a concentration in the Northwest where some of the largest manufacturers of this type of plant are found. There is no apparent pattern of concentration of plants caused by the type of standard adopted by various states. Rather, most states seem to have considered the individual applications for the plants.

Figure 1
 NUMBER OF POTABLE WATER SUPPLY PACKAGE PLANTS IDENTIFIED IN US
 (Winter 1979)



SECTION 4

DESIGN

UNIT OPERATIONS

The package plants observed in this study consisted of coagulation/flocculation, clarification, and filtration units. Common methods of achieving these processes in package water treatment plants are summarized below. Information on specific models on the market follows.

Rapid Mix

Methods used include mechanical mixers, baffled mixing, and in-line mixing.

Mechanical mixers have the advantages of little head loss and varying rotation speed to adjust for variations in raw water quality and/or coagulation chemicals used. Design practices include less than 10 seconds detention time as compared with 10-30 seconds as listed in Water Treatment Plant Design (4) and 20 to more than 40 seconds depending upon the system velocity gradient as suggested by Gemmell (5).

A summary by Amirtharajah (6) of the available literature on mechanical mixers indicates:

- a square vessel performs superior to a cylindrical vessel,

- stator baffles provide improvement,

- a flat-bladed impeller performs better than a fan or propeller impeller,

- chemicals introduced at agitator blade level enhance coagulation.

Vrale and Jorden (7) concluded the typical mechanical mixer is comparatively inefficient.

Baffled mixing has the advantage of no mechanical equipment that must be kept in repair or replaced. The lower power input in a gravitational system indicates a longer detention time will be required to achieve adequate mixing.

Static in-line mixing is frequently found in package plants. Approximately 200 pipe diameters are required for adequate mixing for a smooth pipe

with a Reynolds number of 10,000 if the source issues into the pipe at the wall with no initial mixing (8). The mixing distance can be reduced if a turbulent jet injects perpendicularly into the pipe wall because the injected fluid is transported away from the wall and produces some initial mixing. Ger and Holley (8) conclude a simple, single point of injection will not fulfill the rapid mixing process requirements. Baffled pipe sections will increase the turbulence thus reducing the distance required for adequate mixing. These units are inflexible in that the turbulence cannot be varied.

The theoretical analysis of rapid mixing is not advanced and the literature on design recommendations is conflicting. As a consequence, the design of rapid mix units is largely empirical.

Colloid agglomeration is probably by both adsorption and entrapment in most water treatment situations. It is impossible to design a single rapid mix unit that is optimum for every situation likely to be encountered in water treatment. Amirtharajah (6) says the minimum of 30 seconds detention required by many states does not meet either the need for the adsorption-destabilization reactions nor the extended time for sweep coagulation and he concludes that "based on present day theory, this seems to be an extremely poor recommendation."

Flocculation

Design of flocculation tanks includes selection of a velocity gradient, reactor shape, and detention time that will enable production of aggregates that can be removed by the sedimentation process.

The size of the tank to achieve a desired level of particle aggregation is determined by the rate at which the aggregation occurs. Compartmentalization of the flocculation tank is reported by Argaman and Kaufman (9) to significantly reduce the overall detention time needed to achieve the same degree of treatment. Hudson (10) recommends a design practice of a minimum of three compartments.

The recommended time of flocculation is reported by Rich as 10 to 30 minutes and in Water Treatment Plant Design (4) as 20 to 60 minutes.

Methods for achieving flocculation in water treatment plants are briefly outlined below.

A) Mechanical Flocculators - Package plant manufacturers provide units with 1 or 2 compartment flocculation tanks and vertical paddles and 10-30 minutes detention time; with square tanks and variable speed paddles and 18-27 minute detention times; and with 2 compartment tanks with variable speed horizontal paddles and 17 minute detention time. Baffles may be included to break up the rotational movement of the liquid.

B) Hydraulic Mixing - These avoid the use of mechanical equipment, but are not as operationally flexible as mechanical units. One manufacturer provides hydraulic mixing via a series of compartments having a 10-30 minute detention time and connected by a large diameter pipe.

C) Sludge Blanket - Several manufacturers use a solids contact process for flocculation. Variations of this process include those with mechanical flocculation in the chamber center and those with no external power input. Power requirements and maintenance of mechanical equipment are minimal compared with mechanical type units.

Amirtharajah (11) favors mechanical flocculation for the operational flexibility needed with a varying raw water quality. It is considered difficult to build a blanket with low-turbidity water. The criticism of solids blanket units being unsuitable for stop-start operation was not found valid by Amirtharajah in field work in Sri Lanka where he found no difference between intermittent and continuous operation with alum floc.

Sedimentation

Sedimentation is typically performed in package plants in either square or round hopper-bottomed tanks or in tubes or lamella separators. Upflow clarification in a solids-contact system is an alternate method for liquid-solids separation.

The performance of the sedimentation step is affected by several design features. The inlet, reported by Canale and Borchard (12) to be the most critical appurtenance, needs to be designed so as to spread the incoming water uniformly over the entire cross-section of the sedimentation tank. In this manner, hydraulic short-circuiting of the tank can be minimized. The importance of this is sometimes disregarded in small plants.

Tube settlers, introduced in the mid-1960's apply the shallow depth principles suggested by the work of Hazen and Camp to reduce the detention time required for sedimentation. O'Connell (13) reports the Chevron configuration has the highest perimeter of any common shape of the same area, and thus the lowest Reynolds number. The tubes are composed of PVC or ABS plastic. Sludge will slide down the plastic surface if the tubes are inclined steeply enough. Slightly inclined tubes must be cleaned by draining when the filters are drained for backwashing.

Conley and Hansen (14) say settling tubes should be located so the bottom of the tubes is at least 4 feet from the bottom of a rectangular clarifier while the top of the tubes should be 1 to 2 feet below the top of the effluent weir.

Walker (15) recommends surface loading rates, in the sedimentation tank itself, of 500 gpd/sq ft as being safe even for cold surface waters. He continues that tanks of less than 15 feet diameter are subject to too much short-circuiting and should have smaller surface rates.

Walker states that surface loading rates of 2 to 3 times those for standard clarifiers are used for high-rate settling units. Canale and Borchardt (12) report detention times of less than 10 minutes are common.

Loading rates in use for package units equipped with tube settlers are 100 and 150 gpd/sq ft.

Package solids contact units on the market use a range of loading rates from 0.6-7 gpm/sq ft and detention times of 40-105 min. Conley and Hansen (14) report that this type of unit reduces the flocculation/settling time to 1 hour, primarily because of superior flocculation, but their opinion is that the skill required to operate sludge blanket clarifiers precludes their use in municipal practice.

Hudson (16) states tubes can be used in solids-contact clarifiers to stabilize the floc blanket. They will reduce surface loadings and help to restrain density current, but Conley and Hansen say that the reduced time may not allow adequate flocculation to be achieved.

Filtration

Package water treatment plants can have either gravity or pressure filters.

Most units are available with dual or multi-media filters. These make greater use of the filter depth. Dual media filters generally consist of a 12-14 inch layer of anthracite coal on top of a 6-15 inch layer of silica sand. The anthracite coal has a specific gravity of 1.35 to 1.75, as compared to the sand's specific gravity of 2.65 so even though particles of anthracite coal are used that are larger than the sand particles, the anthracite with larger voids will remain above the sand after backwashing. Mixed media filters contain a third layer of garnet sand below the anthracite coal and silica sand. The garnet sand has a specific gravity of 4-4.2, and will remain at the bottom of the filter even though it may consist of smaller particles, and thus smaller voids than the silica sand.

The size of the various media should be specified so there is a small amount of intermixing at the interfaces of the layers. Baumann (17) recommends choosing media sizes so that neither substantial intermixing nor a sharp interface between media layers occurs.

Flow rates are 2 or 3 gpm/sq ft for gravity sand filters in package plants on the market and range from 2-6 gpm/sq ft for dual and multi-media filters.

Baumann (17) reports that "with adequate chemical pretreatment and filter design, there is little difference in filtered water quality from filters operated at rates between 2 and 6 gpm/sq ft."

Backwashing rates used in package plants are usually 15 gpm/sq ft. Some units are equipped with a surface wash as an auxiliary for cleaning.

Disinfection

Package plant manufacturers provide equipment for feeding chlorine for pre- and post-disinfection but disinfection is not an inherent part of package plant design. The disinfection systems employed are not unique to package plants. The systems employed at the plants monitored in this study were simple and generally consisted of gaseous chlorinators or pumps for adding chlorine solution.

MANUFACTURERS

Various equipment manufacturers were contacted in an attempt to ascertain the number and types of package plants presently being marketed. At the outset of the study a list of fifteen probable manufacturers compiled in a previous study, were asked to supply product information and lists of installations. Inquiries were later made to twenty manufacturers and suppliers listed in the Thomas Register. Eight companies were found to be presently marketing package potable water treatment plants for municipal use. Manufacturers' equipment briefly described in this section includes units that have wide application and are truly package units, i.e., largely preassembled and providing full treatment. Manufacturers producing package units strictly for special applications such as ion exchange or softening were not included.

Visits were made to four of these manufacturers. The visits were used to gain information concerning the future plans of the manufacturers, their problems and their attitudes toward customers and the various regulatory agencies with which they deal. One manufacturer was introducing a microprocessor that will control the coagulant dose based on effluent turbidity measurements. This manufacturer had also redesigned much of its product line including adjustment of flocculation times and tube settler loading rates. Another manufacturer was beginning to recommend the use of aluminum tanks instead of steel due to the difficulty of guaranteeing rust protection on the steel tanks. The manufacturers had varying amounts of difficulty with state agencies depending upon the state and the manufacturer. One manufacturer had little difficulty while another designed a different plant for each state in which it dealt. All of the manufacturers visited were very competitive. To this end these manufacturers were prepared to provide extensive engineering time to work with a customer or a customer's consulting engineer.

Two manufacturers were contacted that had removed themselves from the municipal package water plant market. These manufacturers removed themselves due to difficulties they encountered in dealing with the many regulations involved in funding and permitting public water treatment plants. These manufacturers now deal almost exclusively with industrial customers.

Products of the eight companies identified as presently marketing package plants are summarized on the following pages.

CULLIGAN USA, NORTHBROOK, ILLINOIS

15-265 gpm Multiple trains can be used

Grit removal - optional - cyclone separator

Rapid Mix - In line chemical addition, not baffled

Flocculation/Sedimentation -

"Contact flocculation in a depth clarifier." Chemically treated influent is introduced at the top of the depth clarifier, which is packed with a coarse media; particulates and floc contact already trapped floc in the media.

Loading rate 7 gpm/sq ft

Filtration - Pressure Filter

- 18 in anthracite 0.67 mm effective size
- 9 in Calcined Aluminum Silicate 0.42 mm effective size
- 3 in garnet sand 0.37 mm effective size
- Surface loading rate 7 gpm/sq ft
- No surface wash
- Header lateral underdrain

ENVIRONMENTAL CONDITIONERS, INC. VANCOUVER, WASHINGTON

Rotoflow C, D (10-250 gpm) Rotoflow E, F (10-400 gpm)

Rapid Mix - Static in line mixing

- Baffled pipe mixer - 2-6 ft/sec flow velocity
- 1-5 ft mixing distance

Flocculation -

Mechanical - Vertical paddles

- Paddle tip speed variable
- Detention time 10-30 min
- 1 or 2 compartments

Hydraulic - A series of compartments connected by large diameter pipe

- Detention time 10-30 min

Sedimentation - Rotoflow C+D systems do not use sedimentation

- Rotoflow E+F systems use open tank or tube sedimentation
- Tube loading rate 150 gpd/sq ft

Filtration - Dual media gravity filter

- 18-24 in anthracite effective size 1.0 mm
- 6-12 in silica sand effective size 0.45-0.55 mm

- Mixed media gravity filter

- 18 in anthracite effective size 1.0 mm
- 9 in silica sand effective size 0.45-0.55 mm
- 3 in garnet sand effective size 0.25 mm
- 3 in garnet effective size 2. mm

- Header lateral underdrain

- Filter loading rate 2.-5. gpm/sq ft
- All units equipped with surface wash

GENERAL FILTER CO., AMES, IOWA

- Rapid Mix - Chemical solutions are added at the top of the mixing zone and influent enters from the bottom. A mechanically driven propeller mixes the influent and chemicals.

Flocculation/Sedimentation

- Flocculation occurs in a cone shaped zone contained in a solids contact unit. Effluent flows down and radially outward then up through a sludge blanket. Sedimentation occurs in the upflow portion of the solids contact unit.

Filtration - Anthrafilt media
Mechanical underdrain

INFILCO DEGREMONT, RICHMOND, VIRGINIA

Rapid Mix - Treatment chemicals, influent and recycled precipitate
are mixed in a cylindrically shaped mix chamber with a
mechanical mixer.

Flocculation/Sedimentation

- A large cylindrical zone surrounding the rapid mix chamber promotes solids separation. At the bottom of this zone the solids are drawn into a conically shaped chamber. A portion of the solids slurry is discharged while the rest is recycled up into the rapid mix chambers.

Filtration - Sand or dual media
- Gravity or pressure
- Filtration rates 2-6 gpm/sq ft
- Header lateral underdrain

MET PRO INC., HARLEYSVILLE, PENNSYLVANIA 10-900 gpm

Rapid Mix - Series 2000 uses a square tank with a mechanical mixer.

Flocculation - Series 2000 uses a square flocculation tank with a
variable rate vertical paddle mixer. Retention
time in the flocculator is approximately 18-27 min

Sedimentation - Series 2000 uses a cylindrical tank for a clarifier.
Detention time in the clarifier varies from 60 to 70 min

Flocculation/Sedimentation - Model 1300-100 (166 gpm) upflow
Solids contact, detention time 45 min

Filtration - Gravity Filter - Surface loading 2.8-4 gpm/sq ft
Backwash rate 15 gpm/sq ft
Dual media 18 in anthracite
12 in silica sand
Header lateral underdrain

- Pressure filters - Media 18 in anthracite
12 in silica sand
 - Surface loading 4 gpm/sq ft
 - Backwash rate 15 gpm/sq ft
 - Header lateral underdrain
 - Air scour @ 5 psi optional

NEPTUNE MICROFLOC, INC., CORVALLIS, OREGON
10-1800 gpm

- Rapid Mix
- In line chemical addition
 - Mixing time 2-6 seconds
 - The mixing distance is variable, field data indicates a distance of approximately 20 pipe diameters
 - The Waterboy Series (10-100 gpm) has a mixing chamber.

- Flocculation
- New units - Flocculation occurs in rectangular two stage compartments
 - d.t. = 17 min
 - Electric paddle mixers, variable speed, 1/4, 1/3, 1/2 horsepower, horizontal shaft
 - d.t. old units = 10-14 min

- Sedimentation
- Sedimentation occurs in tube settlers
 - Tube shape - split hexagon
 - Tube overflow rate 100 gpd/sq ft

- Filtration
- Mixed media filter
 - 18 in anthracite 1.0-1.2 mm effective size
 - 9 in silica sand 0.45-0.55 mm effective size
 - 3 in garnet sand 0.25-0.35 mm effective size
 - Surface loading 5. gpm/sq ft
 - Backwash rate 15. gpm/sq ft
 - Header lateral underdrain

PERMUTIT CO., PARAMUS, NEW JERSEY
15-2100 gpm

- Rapid Mix - In line chemical addition or mixing in an inlet flume

- Flocculation/Sedimentation - Upflow solids contact units which use a sludge blanket for flocculation and sedimentation in one vessel

- Centrafilter (15-115 gpm) - d.t. = 3 hr 28 min
rise rate = 0.53-0.61 gpm/sq ft

- Precipitator (60-920 gpm) - d.t. = 60 min or 40 min with settling tubes
Rise rate = 1.25 gpm/sq ft

- Permujet (350-2100 gpm) - d.t. = 90-105 min
Rise rate = 1.0 gpm/sq ft

- Filtration - 24 in silica sand 0.45-0.60 mm effective size
- Disc strainer underdrain
 - Filter rate 2 or 3 gpm/sq ft
 - Backwash rate 15 gpm/sq ft

WESTERN FILTER CO., DENVER, COLORADO
30-200 gpm

Rapid Mix - "Reverse involute" flash mixing chamber

Flocculation/Sedimentation

- Flocculation is promoted via solids contact employing a sludge blanket. The solids are kept in suspension with a mechanical mixer housed in a conically shaped 'downcomer' chamber below the flash mix chamber. Effluent from the 'downcomer' flows radially outward and upward to launders equipped with weirs. The launders conduct the effluent to a filter.

Filtration - Single or dual media

Single media depth 24 in

Media: Silica sand 0.45-0.55 mm effective size

Anthrafilt 0.6-0.7 mm effective size

Granular carbon 14 x 40 mesh

Filter loading 2 or 3 gpm/sq ft

Backwash rate 15 gpm/sq ft

Header lateral underdrain

SECTION 5

PROCEDURES

FIELD PROCEDURES

The intent of the field research was to evaluate water quality data from package water treatment plants to determine if they consistently meet federal and state drinking water standards. In addition to water quality determinations, the operators' responsibilities and the designs of the various units were to be studied. A previous survey of package plants in nearby states included analysis of grab samples taken at several plants (18). Data from these samples indicate that some of the sites were not meeting drinking water requirements. The limitations of a single grab sample preclude assessing the ability of package plants to consistently meet the drinking water standards. Sampling from selected sites on a continuing basis increases the ability to assess the plants' performance. Variability of the source water during seasonal changes may have a large impact on these plants' capabilities. The wetter seasons of autumn and spring may present difficulties in turbidity and/or color removal. The intent was to observe and sample from package water treatment plants on a routine basis over an extended period.

The previously mentioned survey of package water plants conducted during the autumn of 1977 was used to identify prospective sites for use in this research. The survey provided knowledge of plant ownership, manufacturer and sources of water. The survey included comments on the level of maintenance and staffing of each facility. From this information, a list of potential plants was made. Well operated plants were selected that included various source waters and manufacturers. Emphasis was placed on identifying plants supplying households rather than plants serving parks or privately owned resorts since plants in year-round operation were desired. While certain chemical and physical analyses were to be performed at the various water plants, it was known that the microbiological analyses would have to be performed in the more controlled environment of a laboratory, so the availability and proximity of suitable laboratory space were a part of the selection criteria for prospective water treatment plants.

Preliminary visits were made to confirm the previous survey data, measure travel time to the nearest laboratory, and to determine the level of cooperation that could be expected at each site. Eleven package plants were visited on the preliminary trip (Feb. 22-Mar. 3, 1979). Information was gathered concerning the operation of each plant, the number of operators, their background and training, and the analyses performed routinely. Samples of the raw water were collected and analyzed for inorganic pollutants. The appropriate individual in the state health department was asked about the availability of

laboratory space, incubators, and access to an autoclave for use in bacteriological determinations.

Based on the above criteria, the package plants listed in Table 3 were chosen for evaluation. These plants are labeled as sites W, T, V, R, P, and C.

Sites using groundwater sources were not selected owing to water quality consistency and consequent ease of operation. Five of the six plants were made by Neptune Microfloc and provided water to cities or unincorporated towns. The sixth plant was a Permutit system located at a state park that operated all year.

A typical field trip lasted approximately five days. A different water treatment plant site was visited each day during at least the first three days of the trip. Chemical analyses were performed at the site and microbiological samples were collected. The samples for microbiological analyses were taken to the state laboratory. On days subsequent to the first one, any necessary counting and/or transferring of colonies was also done upon arrival at the state laboratory. Often after the three sites were visited and while the microbiological samples were incubating, the plants were revisited to gather more data or to consult in plant operations.

The field trips were conducted from June 1979 through April, 1981, according to the schedule in Table 4. Interruptions occurred due to weather and the necessary support work. Field trips were taken approximately every other week thus insuring monthly observation of each plant through seasonal changes and varied environmental conditions.

The intent of the initial field trips was to observe the operation of the plants, to perform chemical analyses side by side with the operator and to collect treatment and distribution system samples for microbiological analyses. Observation of the operator included seeing that person change coagulant doses and perform any necessary routine maintenance. This facilitated evaluation of the operational requirements of these plants. The side by side chemical analyses provided confirmation of the operator's data on the daily operational log, which was submitted to the state health department. Provided the results of the side by side analyses were comparable, the operational logs were to be relied upon as a source of performance data for this research. The microbiological samples were analyzed for total coliforms and the plant effluent and distribution system samples were analyzed for standard plate count.

The side by side analyses with the operators generally compared quite favorably. As more field trips were completed and the operational logs of the operators were studied, doubts arose as to the validity of some of the data from a few of the plants. While the results of the side by side analyses were similar, these data did not always appear in the operational logs. Growing familiarity with the operators permitted questioning of those at the installations with discrepancies in their logs. The data, most often effluent turbidity, were not reported faithfully when they were greater than the standard 1 ntu, out of fear of repercussions from the state health department. This meant some of the monthly operational logs could not be used as sources of performance data of these plants.

TABLE 3 FACILITIES IN STUDY

SITE	MODEL YEAR	DESIGN FLOW RATE (gpm)	POP. SERVED/ NO. OF METERS	AVG. VOLUME PER DAY (gals)	GROUP SERVED	TYPE OF DISTRIBUTION PIPE USED	SOURCE
W	Neptune Microfloc AQ-40 1973	200	1500/552	110,000	city	PVC	surface impoundment
T	Neptune Microfloc AQ-40 1973	200	1000/360	78,000	city	PVC, cast iron asbestos cement	surface impoundment
V	Neptune Microfloc AQ-40 1976	200	-----/423	72,000	PSD*	PVC	river
R	Neptune Microfloc AQ-112 1972	560	-----/1680	330,000	PSD*	PVC	river
P	Neptune Microfloc Water Boy 1972	100	-----/411	82,000	PSD*	PVC	surface impoundment
C	Permutit Permutjet 1971	200	State Park	57,000	State Park	asbestos cement	river

* PSD - Public Service District

TABLE 4 DATES OF FIELD TRIPS

MONTH	SITE W	SITE R	SITE V	SITE T	SITE C	SITE P
May 1979	10	11	--	--	--	--
June 1979	--	--	--	07	08	11
July 1979	16	20	--	--	31	--
Aug 1979	13	14	--	01, 28	27	29
Sep 1979	--	--	--	--	--	--
Oct 1979	03	01, 30	--	15	16	15
Nov 1979	--	--	--	13	14	13
Dec 1979	04	05	06	--	--	--
Jan 1980	23	23	22	08	07	08
Feb 1980	--	04-06	--	--	--	--
Mar 1980	--	28-01	04-06, 17-20 31-02 14-17	--	--	--
Apr 1980	--	12	--	--	--	--
May 1980	--	02-04, 09	--	--	--	--
June 1980	11	--	10	25	23	23
July 1980	--	--	--	--	--	--
Aug 1980	--	--	--	--	--	--
Sept 1980	--	--	--	--	--	--
Oct 1980	--	--	--	28	--	--
Nov 1980	19	18	17	--	27	28
Mar 1981	--	30	31	--	--	--
Apr 1981	1	--	--	15	14	13

The data from the visits began to show at least two sites were having difficulty meeting the effluent turbidity standard of 1 ntu. Extended periods were spent at these plants having difficulties.

The chemical analyses performed routinely for this study are listed in Table 5. On occasion, samples were taken for later trihalomethane analyses or for determination of primary and secondary contaminant levels.

Samples at each water treatment plant were collected from the raw water, the plant effluent and the distribution system. Five of the six plants had raw water taps from which the influent was sampled. The remaining plant was sampled directly from its river source. All of the plants had sinks for use in chemical analysis of their treated effluent. These were used as sampling sites for the finished water. The sinks had water piped to them from the clearwell thus providing a composite of the plant effluent produced over a period of time. Two samples from each plant's distribution system were collected at various public places, e.g., schools, service stations, restaurants. Attempts were made to have one sample from an intermediate point of the distribution system and one from an end or extreme point of the system. Most of the plants' distribution systems were sampled several times and an effort was made to change the sampling points each time. On occasion, the same sampling sites had to be used again because of the small number of accessible public sampling points within each system.

Autoclaved nalgene bottles containing sodium thiosulfate to reduce any chlorine were used for microbiological sample collection. Total coliform tests using the membrane filter technique were performed on all samples from each site. M-Endo agar media was used because it could be prepared at the University of Cincinnati laboratory, chilled, and transferred to either of the two field laboratories for use during that week. One plant per field trip was sampled on a Monday and that plant's membrane filter total coliform determination was confirmed via the multiple tube fermentation technique.

The standard plate count examination was made on the plant effluent and distribution system samples. The agar was prepared at the U.C. laboratory, allowed to solidify and then transported to either of the two field laboratories. Duplicate plates of three different dilutions were run for each of the three samples from each site.

Samples were sent to USEPA's Cincinnati Laboratory for analysis of chemical contaminants in the primary and secondary Drinking Water Regulations. Samples from each water treatment plant were also collected for trihalomethane analysis by the University. The level of trihalomethane in the plant effluent was measured along with the terminal 2 day THM concentration of each plant's raw water.

The samples of the plant effluent used for measuring the levels of trihalomethanes present were collected in 40-ml vials containing sodium thiosulfate to quench any chlorine residual present. The sample vials were sealed, without any air space, with a teflon lined septum and a screw cap. The quenching of the chlorine prevents any further formation of trihalomethanes, thus the sample is essentially an instantaneous trihalomethane measurement. By capping the sample with no airspace, volatilization and loss of the THMs is

TABLE 5 ANALYTICAL METHODS

SITE	PH	ALKALINITY	HARDNESS	TURBIDITY	FREE Cl	OTHER
W	color com- parator	methyl orange ti- tration	titration	nephelometer Hach 2100A	effluent and system; DPD color compar- ator	iron & manganese color comparator
C	pH meter	methyl orange ti- tration	titration	nephelometer HF DKT-1000	effluent only DPD color comparator	
T	colorimeter	methyl orange ti- tration	titration	nephelometer Hach 2100A	effluent and system; DPD color compar- ator	
V	pH meter	methyl orange ti- tration	titration	nephelometer Hach 2100A	effluent only DPD color comparator	iron, color comparator
R	colorimeter	methyl orange ti- tration	titration	nephelometer Turner Designs	effluent only DPD color comparator	
P	pH meter	Hach kit with dropper bottle	titration with dropper bottle	nephelometer Hach 2100A	effluent and system; DPD color compar- ator	iron, color comparator
Project	pH meter	methyl purple ti- tration	titration	nephelometer Turner Designs	effluent and system; DPD and spectro- photometer	temperature

prevented. The reaction time of the chlorine with any precursor material present is the sum of the plant treatment time and the clearwell retention time.

The THM formation potential is a measure of the level of precursor material present in a water sample. The influent sample was chlorinated with a sufficient amount of chlorine to maintain a free residual over a 2 day incubation period which approximated the theoretical detention time found in the distribution systems. Upon completion of the incubation period the chlorine residual in part of the sample was measured and part was quenched and stored in a 40 ml vial with no headspace to prevent volatilization. The level of the THMs present, upon incubation and quenching, is a measure of the terminal 2 day THM concentration of the sample. The formation potential is defined as the difference between the terminal THM concentration and the instantaneous THM concentration. In this work, the instantaneous THM concentration of the raw water samples was not measured and was assumed to be very low or zero. The terminal concentration is that reached after incubation for a predetermined period at a predetermined temperature and pH. The incubation temperature was not controlled at the temperature of the influent when the samples were taken. The samples were incubated at room temperature and the pH was not controlled. This makes it impossible to compare the raw water terminal THM samples with the effluent water instantaneous samples. The terminal THM concentrations will serve only as an indicator of the level of precursor material present.

The analyses were performed on a Varian 2800 Gas Chromatograph (G.C.) equipped with a Hall Electrolytic Conductivity Detector and a Huston Instruments 2-pen strip chart recorder. The carrier gas was Nitrogen at a flow rate of 55 ml per minute.

The purge apparatus was a 50 ml unit with Nitrogen purge gas at a rate of 40 ml per minute. The trap was a 6" x 1/8" column filled with Tenax G.C. packing.

Twenty milliliter samples were purged and trapped for 11 minutes at 25°C. At the end of the 11 minutes, the trap was attached to the cool (45°C) G.C. column and desorbed for 6 minutes. The column was then heated at a rate of 24°C/min to 117°C held 3 minutes, then temperature programmed at a rate of 6°C/min up to 195°C and held for the remaining time in the 27 minutes total run time.

The peak heights were compared to those produced by standards analyzed in the same fashion each day of analysis.

SECTION 6

CASE STUDIES

TREATMENT PROCESS DESCRIPTION

The state health department having jurisdiction over the 6 facilities studied required a class I operator's license for operators at facilities using groundwater sources and a class II license at facilities using surface water sources. Water treatment plants having inadequately licensed operators were requested to retain an adequately licensed operator as a supervising operator. The supervising operator visited the plant approximately weekly to check on the plant's operation, instruct the staff and help with any operational problems.

Pertinent data for each plant are summarized in Tables 3 and 6. Five of the 6 plants studied were manufactured by Neptune Microfloc Inc., and were functionally similar. A general description of these units follows.

The 5 Neptune Microfloc units had influent rate controlling valves. Treatment chemicals were added as solutions directly into the influent pipe near the influent valve. Chemical mixing occurred in the influent pipe and/or in a mix chamber. The influent then entered the flocculator at the top while the flocculator effluent was drawn off from near the bottom. The flocculators employed variable speed vertical paddles for agitation. Four of the 5 units had a horizontal baffle plate at mid-depth to prevent short circuiting.

Sedimentation occurred in tube settlers. Each tube was hexagonal in shape, approximately 2 in. wide and 39.5 in. long. The tube banks were inclined upwards at a $7\frac{1}{2}^\circ$ slope to facilitate solids removal in the backwash cycle when the direction of flow was reversed.

Four of the 5 units had float depth controls that pneumatically controlled the effluent valves. The other plant had a float that was mechanically connected to the effluent valve. Four of the 5 facilities had below grade clearwells which contained the intakes for 2 high service pumps and 2 backwash pumps. The fifth unit had an above grade clearwell that gravity fed a wet well containing the high service pumps' intakes.

Each of the 5 facilities had 1 control panel which controlled the influent pump or pumps, the influent rate control valve, the chemical feed pumps, the effluent valves, the high service pumps, backwash pumps and backwash valves. A cam timer in the control panel regulated the backwash cycle. Upon manual initiation or due to filter headloss beyond a certain limit the cam timer would shut off the plant and backwash the appropriate filter. At

TABLE 6 TREATMENT PROCESS CHARACTERISTICS

SITE	PRE-CHEMICAL ADDITION	RAPID MIX type	RAPID MIX d.t. sec.	FLOCCULATION type	FLOCCULATION d.t. min.	SEDIMENTATION		FILTRATION media	FILTRATION rate $\frac{gpm}{ft^2}$	NOTES
						type	loading $\frac{gpd}{ft^2}$			
W	Cl, alum. soda ash	in pipe	3	paddle	12.8	tubes	100	mixed anthracite 18 in silica sand 9 in garnet sand 3 in	5	poly added prior to tubes
T	Cl, alum. soda ash, poly	in pipe	3	paddle	12.8	tubes	100	mixed same as above	5	post soda ash
V	Cl, alum. soda ash, poly	in pipe	3	paddle	14	tubes	100	mixed same as above	5	post sodium hexameta-phosphate
R	Cl, alum. soda ash poly	chamber 30		paddle	10	tubes	100	mixed same as above	5	
P	Cl, alum. soda ash, carbon (summer)	chamber -- not used		paddle	10	tubes	150	mixed same as above	5	
C	Cl, alum. soda ash, poly	in pipe --		upflow solids contact 2 hr. d.t. rise rate = 1 gpm/ft ²				silica sand 24 in	2	soda ash added prior to filtration

one facility the cam timer was not working properly and had to be turned manually. The tube settler chamber associated with the filter to be back-washed rapidly drained at this time cleansing the tubes of settled material.

Site W

The chief operator at site W was not licensed by the state, although he has been operating this facility since its construction. The other operator was in the process of becoming licensed at the close of the study period. The staff's responsibilities included plant operation, distribution system maintenance and meter reading. The staff occasionally performed tasks for the city that were not related to the water treatment plant. The staff estimated however, that 85-90% of their time was spent at the water treatment plant, which was in operation an average of 9 hours per day.

The plant (see Figures 2 and 3) was started early each morning. The chemical solutions were checked and more were made as necessary. The pH and turbidity were measured and recorded hourly throughout the time the unit was operating. Whenever the plant had to be left unattended an operator returned hourly to insure the unit's proper operation.

Site W water quality characteristics and microbiological analysis data are found in Table 7. The raw water was of consistently high quality (4-30 ntu) as was the plant effluent, except for one effluent turbidity value of 2 ntu. The operator thought this value was the result of a low flocculator pH caused by efforts to improve color removal. Coliform levels entering the plant ranged from 2 to 4,400 per 100 ml. Effluent chlorine residuals were above 1 mg/l but some distribution system samples had no free chlorine residual. No coliforms were found in any effluent or distribution samples and 7 of 9 standard plate counts were less than 20 per ml.

THM values are reported in Table 8. Effluent instantaneous levels were approximately at the 100 µg/l limit set for TTHM by the USEPA for water distribution samples of systems serving 10,000 or more population. The raw water terminal TTHM values of 184 and 321 µg/l indicated high concentrations of precursor material.

Results of the chemical analyses performed by USEPA are found in Table 9. All of the primary and secondary contaminant levels were met in the effluent and distribution system samples collected. The influent water was also of high quality with only the secondary limits for color, iron, and manganese exceeded.

A major contribution to the consistent high quality effluent produced at site W was the operational staff. The chief operator has been operating this plant since its start up in 1973 and this is the only staff in the study that recorded hourly turbidity and pH measurements. Another factor contributing to the effluent quality was the uniform quality of the source reservoir. The maximum influent turbidity recorded by the study was 29.7 ntu. The operator indicated that the uniform quality of the source is typical for this plant. The monthly operations reports submitted to the state show the influent turbidity exceeded 50 ntu on 2 occasions for 2 days between May 1979 and July 1980.

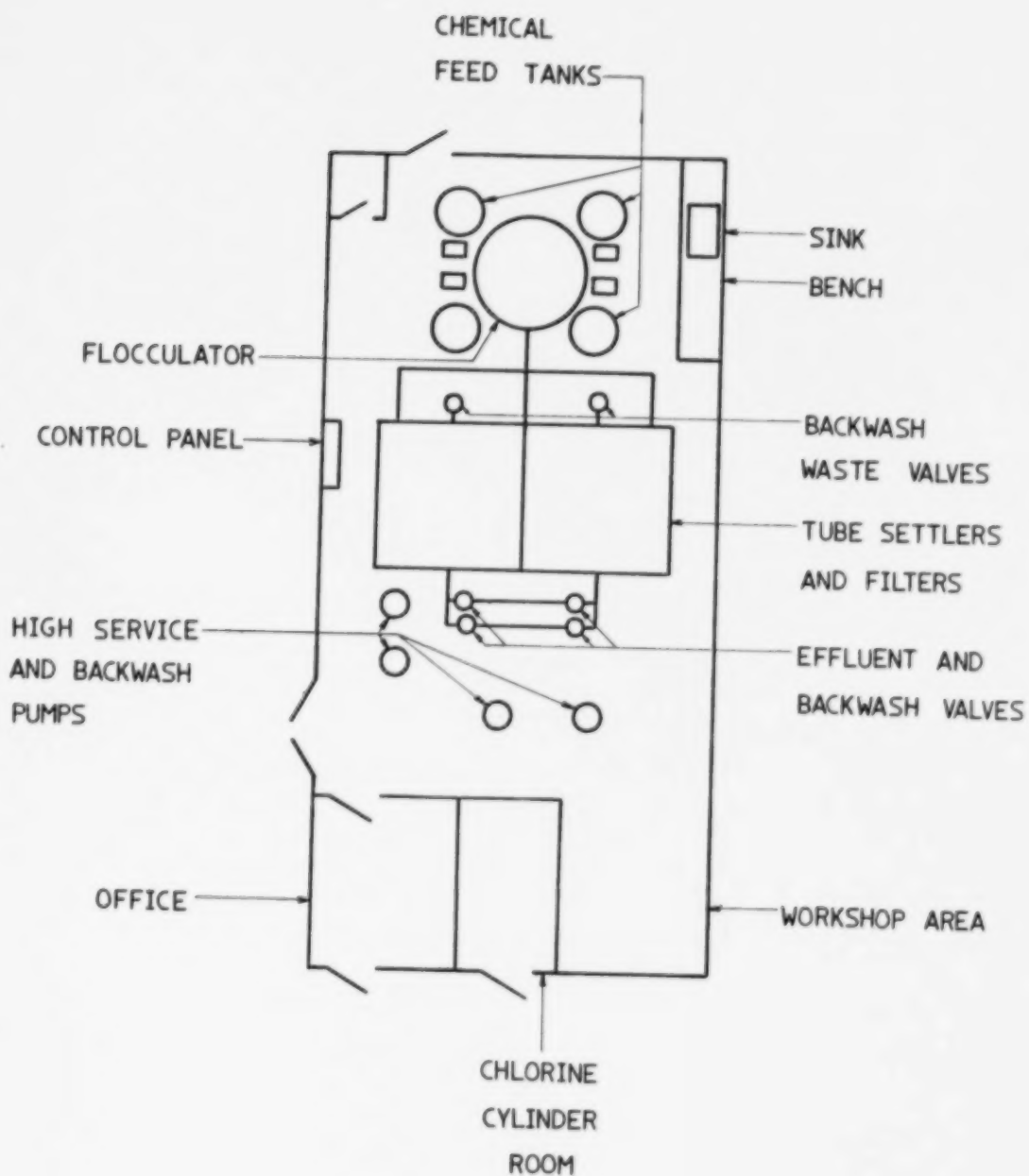


Figure 2. Site W Facility layout

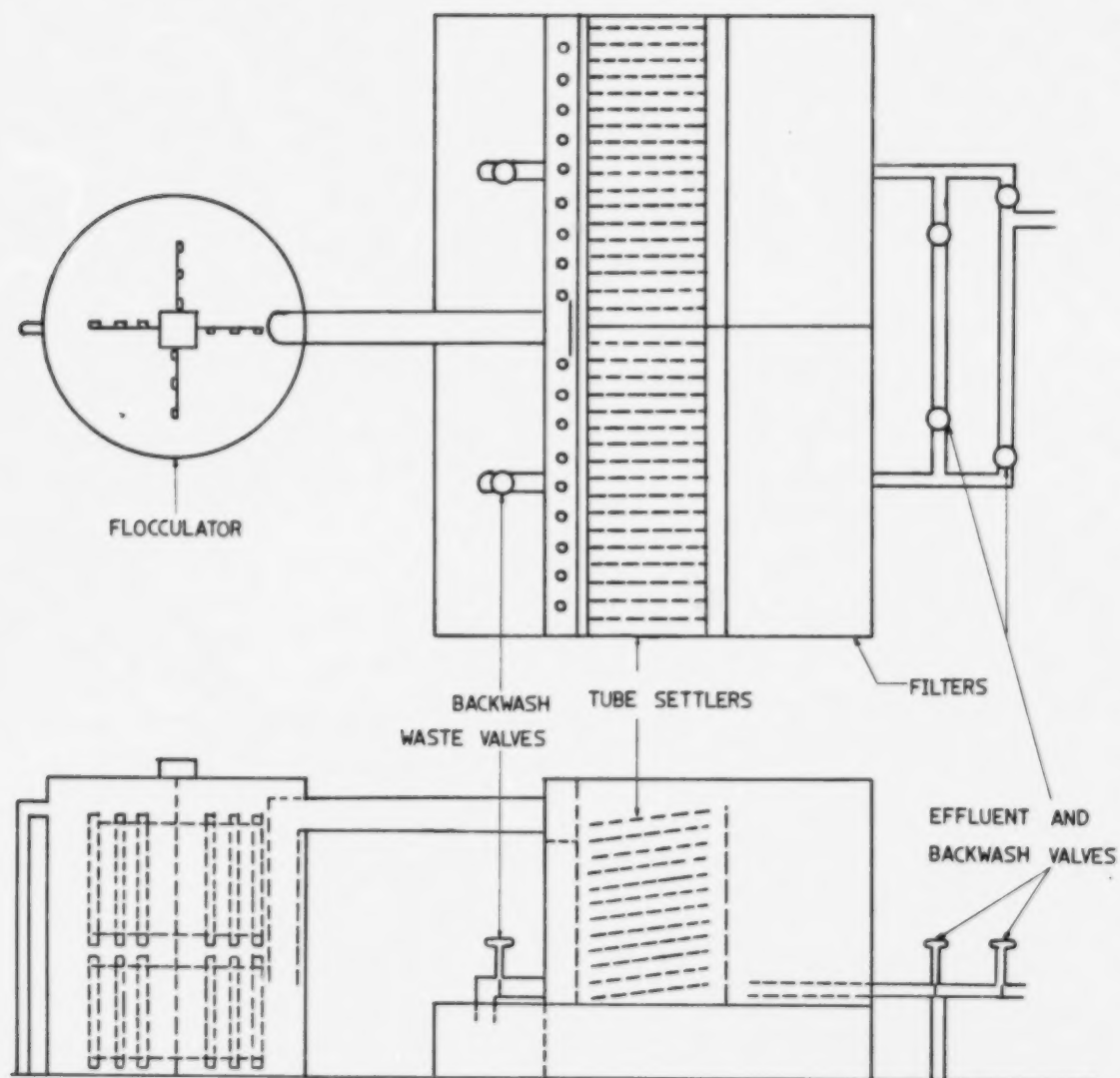


Figure 3. Site W Neptune Microfloc AQ-40 200gpm

TABLE 7 SITE W MICROBIOLOGICAL ANALYSES AND WATER QUALITY CHARACTERISTICS

DATE	RAW Total Coliforms 100 ml	CLEANWELL EFFLUENT			1ST DISTRIBUTION			2ND DISTRIBUTION		
		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml
7/16/79	18	2.0	-	-	1.4	< 1	-	1.1	< 1	-
8/13/79	4,400	2.0	< 1	-	1.0	< 1	-	1.1	< 1	-
10/03/79	640	1.4	< 1	4	0.0	< 1	1	0.0	< 1	300
10/29/79	4	1.6	< 1	< 1	0.7	< 1	150	0.0	< 1	< 1
12/04/79	160	> 2.	< 1	< 1	1.4	< 1	< 1	0.0	< 1	18
1/24/80	31	1.0	< 1	-	0.9	< 1	-	0.1	< 1	-
6/11/80	26	1.6	< 1	-	0.8	< 1	-	1.6	< 1	-
11/19/80	280	1.7	< 1	-	1.1	< 1	-	0.0	< 1	-
4/01/81	2	1.3	< 1	-	0.8	< 1	-	0.6	< 1	-

DATE	pH	ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
5/10/79	7.2	-	82.	92.	-	-	0.9	1.4
7/16/79	-	64.	82.	100.	100.	5.0	0.3	2.0
8/13/79	7.6	28.	102.	92.	82.	4.2	0.4	2.0
10/03/79	-	69.	77.	67.	68.	19.	0.8	1.4
10/29/79	6.9	86.	80.	71.	78.	9.2	2.0	1.6
12/04/79	7.5	50.	78.	78.	73.	11.5	0.3	> 2.
1/23/80	7.5	48.	80.	66.	86.	12.0	0.2	1.0
6/11/80	7.4	55.	80.	99.	99.	11.0	0.3	1.6
7.2	7.5	67.	80.	77.	78.	29.7	0.9	1.7
11/19/80	7.1	47.	91.	77.	90.	12.8	0.2	1.3
4/01/81	7.2	40.	51.	-	-	-	-	-

TABLE 8 SITE W TRIHALOMETHANE ANALYSIS

INSTANTANEOUS THM						
DATE	SAMPLE	CHCl ₃ (g/l)	CHCl ₂ Br (g/l)	CHClBr ₂ (g/l)	CHBr ₃ (g/l)	TOTAL THM (g/l)
10/29/79	Effl.	101.	2.2	N.D.	N.D.	103.
06/11/80	Effl.	92.7	8.9	N.D.	N.D.	102.
TERMINAL THM (2 DAY)						
DATE	SAMPLE	CHLORINE DEMAND (mg/l)	CHCl ₃ (g/l)	CHCl ₂ Br (g/l)	CHClBr ₂ (g/l)	CHBr ₃ (g/l)
06/11/80	Infl.	1.76	139.	45.	N.D.	N.D.
06/11/80	Infl.	1.91	288.	33.5	N.D.	N.D.
N.D. - None Detected						
TOTAL THM (g/l)						
						184. 322.

TABLE 9 SITE W CHEMICAL ANALYSES PERFORMED BY USEPA (mg/L except as noted)

	FEB. 1979			JUNE 1980			OCT. 1980			MARCH 1981		
	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.
PRIMARY MCL												
ARSENIC (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BARIUM (1.)	0.25	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
CADMIUM (0.01)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
CHROMIUM (0.05)	0.011	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
FLUORIDE (1.4 to 2.4)	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
LEAD (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
MERCURY (0.002)	0.0009	0.0018	< 0.0005	0.0018	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
NITRATE-N (10.)	< 0.3	-	< 0.3	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
SELENIUM (0.01)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILVER (0.05)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SECONDARY MCL												
CHLORIDE (250.)	< 10.	-	< 10.	-	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
COLOR (15 C.U.)	40.	3.	50.	3.	2.	3.	3.	2.	3.	15.	2.	2.
COPPER (1.0)	< 0.02	0.03	0.06	0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
IRON (0.3)	0.59	0.26	0.84	0.26	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.25	< 0.1	< 0.1
MANGANESE (0.05)	0.04	0.12	0.54	0.12	0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.09	< 0.03	< 0.03
SULFATE (250.)	38.	40.	31.	40.	49.	48.	46.	44.	61.	44.	60.	60.
TOTAL DISSOLVED SOLIDS (500)	70.	139.	116.	139.	160.	164.	158.	123.	158.	123.	164.	165.
ZINC (5.)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
ALKALINITY												
CALCIUM	31.	62.	41.	62.	66.	70.	70.	20.	50.	20.	50.	49.
HARDNESS	15.8	25.	18.0	25.	18.7	18.4	18.1	17.0	26.7	17.0	25.6	26.0
MAGNESIUM	62.	92.	64.	92.	64.	64.	65.	76.	96.	76.	94.	92.
SODIUM (20.)*	4.50	7.22	4.97	7.22	4.98	4.95	4.87	5.21	5.43	5.21	5.47	5.46
SPECIFIC CONDUCTANCE (µMHOS) @ 25°C	4.5	8.9	6.0	8.9	29.8	31.5	29.3	7.8	15.4	7.8	16.1	16.3
	146.	229.	174.	229.	276.	283.	270.	196.	267.	196.	266.	266.

*The USEPA promulgated, on August 27, 1980, a sodium monitoring requirement to become effective in February 1982. While no maximum contaminant level has been set for sodium, the preamble to the amendments indicates that 20mg/l should be the goal.

Site T

The operational staff at site T consisted of 2 positions. These 2 positions were held by 4 different people during the study period of 16 months. One operator held his position for the first 6 of the 8 field trips conducted at this site. This operator became a class I licensed operator during this period. At the state health department's request a consultant operator was retained by the city to assist and advise the site T staff. The consultant operator visited approximately once per week. The staff's responsibilities included: plant operation, meter reading, distribution system repair and some work for the city not related to water treatment. When duties outside the water treatment plant required the staff's attention, the facility was left unattended.

The treatment plant (see Figures 4 and 5) was operated an average of 6.5 hours daily. Analyses were performed in the morning. The filters were backwashed based upon effluent turbidity or time. When the operators were inexperienced, they had used filter backwashing as a method of wasting higher than 1 ntu effluent. After backwashing, they adjusted the chemical doses and put the plant back in operation. The cam timer at site T did not function and had to be turned by hand so that the backwash cycle was not timed. Thus, a set volume of water was used to determine the length of the backwash.

Table 10 summarizes the water quality characteristics and the microbiological analysis measured at site T. The maximum influent turbidity was 10.4 ntu. The effluent turbidity exceeded the 1 ntu standard on 2 occasions. The first occasion June 7, 1979 was due to an influent pump failure and consequent extended filter operation to make up for the failure. The second high effluent turbidity resulted from a large distribution system leak repair keeping the operators away from the plant for an extended period. The effluent pH is erratic ranging from 6.6 to 9.5. Raw water total coliforms ranged from less than 10 to 8,900 per 100 ml. Total coliforms were detected in one treated water sample (12/100 ml). The sample was collected at the kitchen sink of a residence and no free chlorine residual was present. Five of the 18 distribution system samples collected had no free chlorine residual although effluent samples ranged from 0.3 to 1.3 mg/l. The standard plate counts of treated water samples ranged from <1 to 110 per ml.

The instantaneous TTHM analysis indicated some levels of TTHM at or near the 100 µg/l limit set by the USEPA for systems serving 10,000 or more population (Table 11). The samples from October 28, 1980 reflect a progression due to their respective greater chlorine contact times. The raw water 2 day terminal TTHM analysis resulted in TTHM concentrations of 440 and 498 µg/l.

The chemical analyses performed by USEPA indicate that all treated water samples had chemical concentrations below the primary maximum contaminant level (MCL) (Table 12). Iron and manganese in 3 and 2 samples respectively were the only secondary MCL's exceeded. The influent water exceeded the secondary limits for color, iron, and manganese.

Seven of the 9 field trips to this facility found the effluent turbidity meeting the 1 ntu standard. The low influent turbidity (3-10 ntu) of the

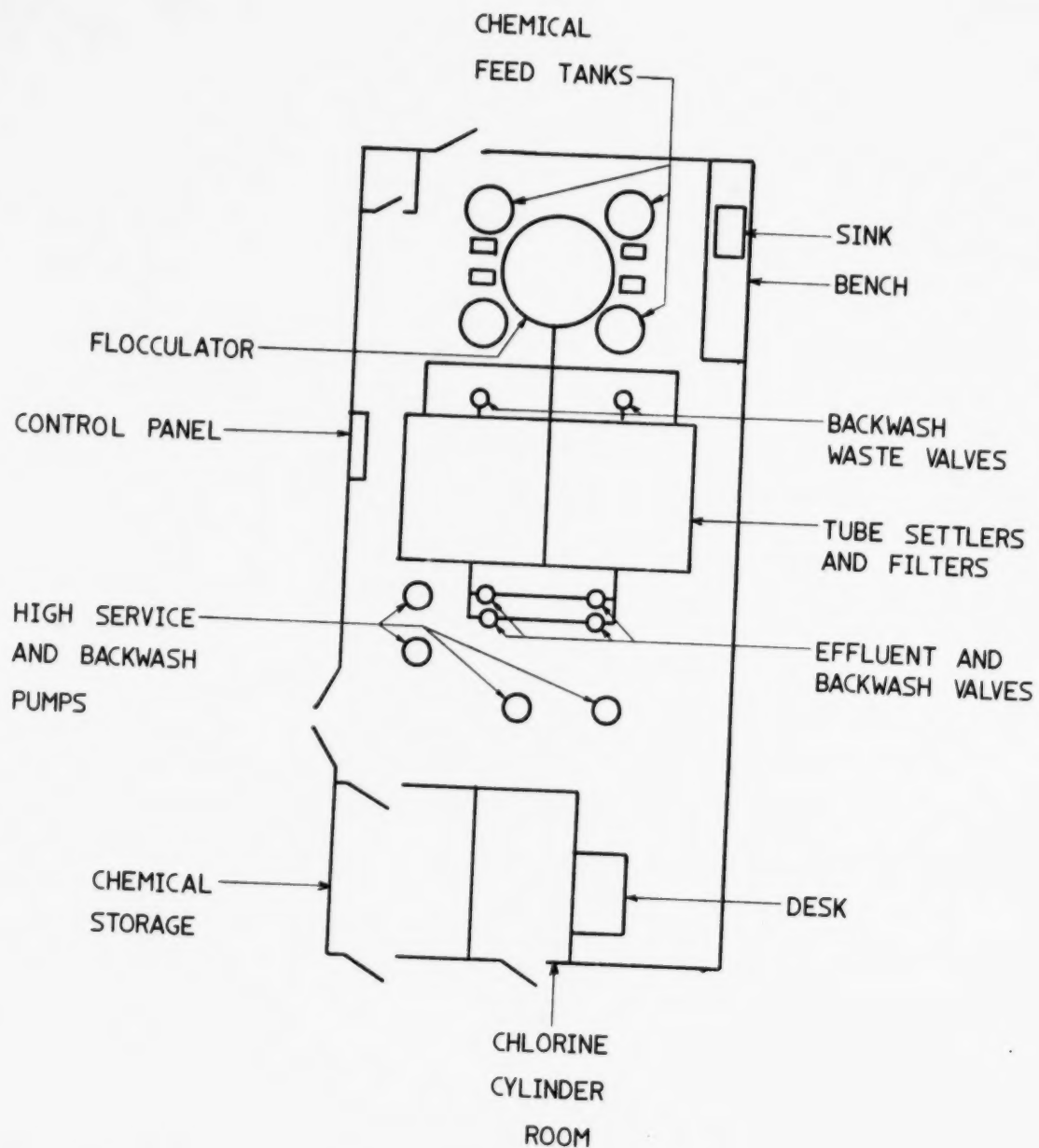


Figure 4. Site T Facility layout

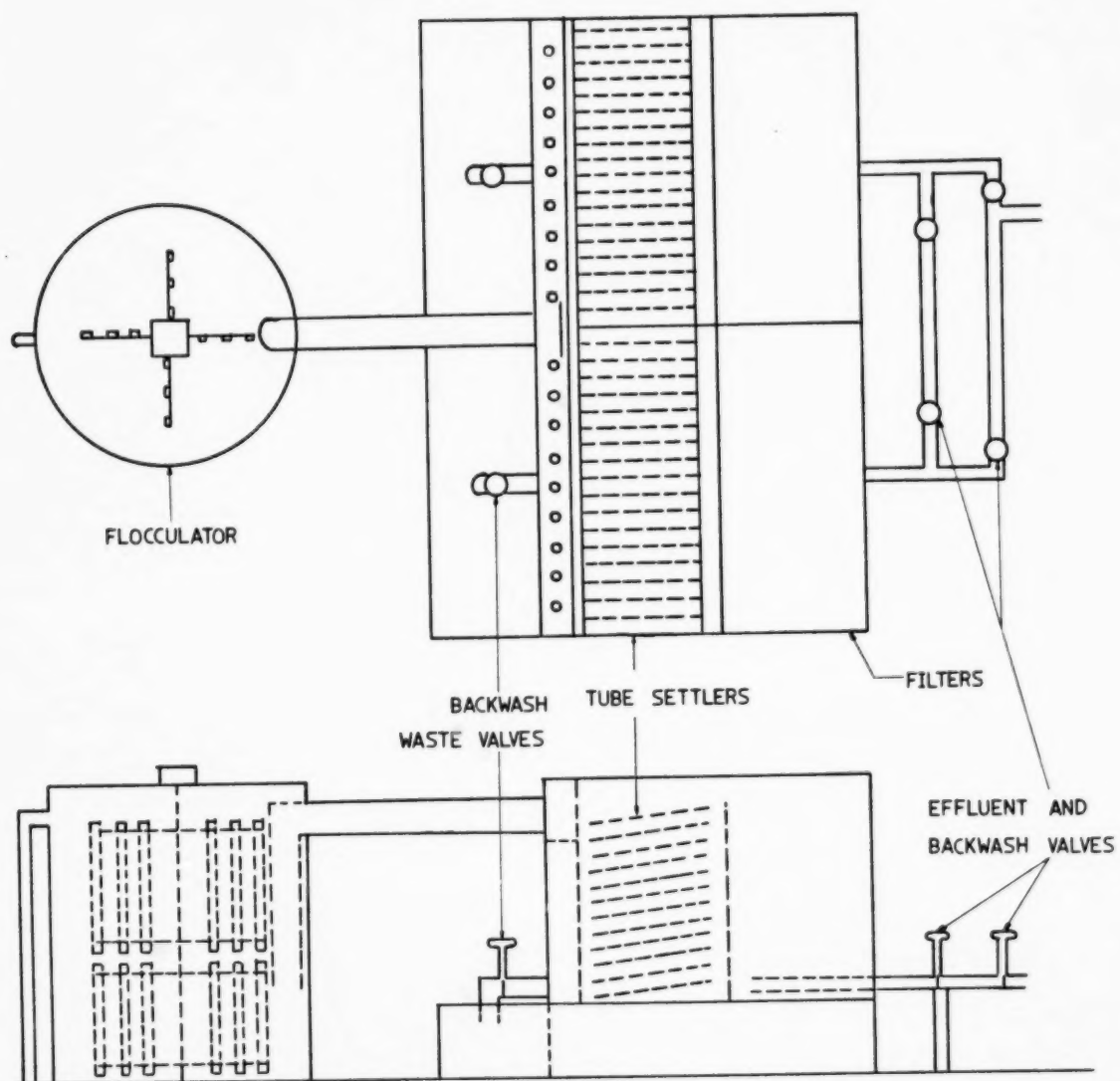


Figure 5. Site T Neptune Microfloc AQ-40 200 gpm

TABLE 10 SITE T MICROBIOLOGICAL ANALYSES AND WATER QUALITY CHARACTERISTICS

DATE	RAW Total Coliforms 100 ml	CLEARWELL EFFLUENT				1ST DISTRIBUTION				2ND DISTRIBUTION			
		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	
6/07/79	80	1.3	< 1	15		1.6	< 1	30		1.0	< 1	10	
7/30/79	8,900	0.3	< 1	110		0.0	12	2		0.0	< 1	36	
8/28/79	190	0.6	< 1	13		0.1	< 1	31		0.0	< 1	40	
10/15/79	140	1.2	< 1	3		0.3	< 1	1		0.0	< 1	1	
11/13/79	12	0.4	< 1	110		0.2	< 1	1		0.6	< 1	1	
1/08/80	14	1.2	< 1	1		0.5	< 1	1		0.5	< 1	3	
6/24/80	< 10	0.4	< 1	1		0.3	< 1	1		0.0	< 1	14	
10/28/80	306	1.0	< 1	4		0.5	< 1	2		0.1	< 1	6	
4/14/81	24	0.7	< 1	< 1		0.2	< 1	29		0.4	< 1	7	

DATE	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l)	
	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent
6/07/79	-	9.2	-	61.	-	-	10.0	1.9	1.3	1.3
8/01/79	6.6	9.1	120.	62.	148.	44.	8.0	0.2	0.0	0.0
8/28/79	6.5	9.5	15.	90.	-	26.	6.0	0.4	0.6	0.6
10/15/79	-	-	7.	34.	17.	18.	3.2	1.1	1.2	1.2
11/13/79	6.5	9.2	34.	35.	15.	15.	3.2	0.2	0.4	0.4
1/08/80	5.6	8.3	9.	35.	-	40.	3.2	0.2	1.2	1.2
6/25/80	6.3	6.6	10.	21.	19.	20.	5.8	0.2	> 2.	> 2.
10/28/80	6.7	6.9	19.	29.	29.	30.	10.4	3.2	1.0	1.0
4/14/81	6.1	9.4	9.	38.	19.	19.	3.4	0.7	0.7	0.7

TABLE 11 SITE T TRIHALOMETHANE ANALYSIS

INSTANTANEOUS THM						
DATE	SAMPLE	CHCl ₃ (μg/l)	CHCl ₂ Br (μg/l)	CHClBr ₂ (μg/l)	CHBr ₃ (μg/l)	TOTAL THM (μg/l)
06/25/80	Effl.	0.2	N.D.	N.D.	N.D.	0.2
06/25/80	Effl.	0.1	N.D.	N.D.	N.D.	0.1
10/28/80	Effl.	78.6	5.7	N.D.	N.D.	84.3
10/28/80	1st Distr.	85.0	7.8	N.D.	N.D.	92.8
10/28/80	2nd Distr.	114.	8.8	N.D.	N.D.	123.
TERMINAL THM (2 DAY)						
DATE	SAMPLE	CHLORINE DEMAND (mg/l)	CHCl ₃ (μg/l)	CHCl ₂ Br (μg/l)	CHClBr ₂ (μg/l)	CHBr ₃ (μg/l)
06/25/80	Inf1.	2.6	288.	152.	N.D.	N.D.
06/25/80	Inf1.	2.9	486.	12.	N.D.	N.D.
N.D. - None Detected						

TABLE 12 SITE T CHEMICAL ANALYSES PERFORMED BY USEPA (mg/L except as noted)

PRIMARY MCL	FEB. 1979			JUNE 1980			OCT. 1980			APRIL 1981		
	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.
ARSENIC (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BARIUM (1.)	< 0.2	< 0.2	0.23	< 0.2	< 0.2	0.21	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
CADMIUM (0.01)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
CHROMIUM (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
FLUORIDE (1.4 to 2.4)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
LEAD (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
MERCURY (0.002)	< 0.0005	0.0009	0.0014	< 0.0005	0.0005	0.0009	< 0.0005	0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
NITRATE-N (10.)	< 0.3	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
SELENIUM (0.01)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILVER (0.05)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SECONDARY MCL												
CHLORIDE (250.)	< 10.	-	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
COLOR (15 C.U.)	8.	30.	70.	3.	6.	11.	10.	2.	8.	3.	3.	3.
COPPER (1.0)	0.07	0.03	< 0.02	< 0.02	< 0.02	< 0.02	0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
IRON (0.3)	0.39	1.35	2.47	< 0.1	0.31	0.56	0.49	< 0.1	0.98	< 0.1	< 0.1	< 0.1
MANGANESE (0.05)	0.07	0.41	0.18	0.08	0.04	0.07	0.06	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SULFATE (250.)	< 15.	< 15.	< 15.	18.	17.	< 15.	< 15.	< 15.	< 15.	< 15.	< 15.	< 15.
TOTAL DISSOLVED SOLIDS (500)	42.	33.	42.	82.	79.	71.	36.	75.	65.	69.	69.	69.
ZINC (5.)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
ALKALINITY												
CALCIUM	5.	10.	15.	36.	32.	27.	4.	30.	22.	28.	28.	28.
HARDNESS	4.1	3.7	6.2	6.3	6.5	8.3	4.6	4.3	3.8	5.0	5.0	5.0
MAGNESIUM	20.	16.	24.	24.	26.	28.	14.	14.	12.	15.	15.	15.
SODIUM (20.)*	0.82	0.71	1.12	1.16	1.09	0.97	0.78	0.82	0.65	0.71	0.71	0.71
SPECIFIC CONDUCTANCE (UMHOS) @ 25°C	5.2	2.6	3.0	20.7	17.9	11.7	4.9	22.0	21.0	20.1	20.1	20.1
	66.	48.	65.	142.	137.	118.	62.	137.	125.	130.	130.	130.

*The USEPA promulgated, on August 27, 1980, a sodium monitoring requirement to become effective in February 1982. While no maximum contaminant level has been set for sodium, the preamble to the amendments indicates that 20mg/l should be the goal.

reservoir source and conscientious operators are responsible for this compliance. Although the operators were inexperienced they did develop methods to achieve compliance.

Site V

The operational staff at site V consisted of 3 men. The PSD employed a consultant operator at the state health department's request due to the lack of a class II license being held by any of site V's staff. The consulting operator worked at a nearby larger water treatment plant that used a source similar to that used by site V so he had some insight into the proper chemical doses for coagulation and flocculation. The close proximity of the consulting operator made him available whenever problems arose. The site V staff's responsibilities included plant operation, distribution system maintenance and meter reading. The plant treated water an average of six hours per day.

Four extended field trips of more than 1 day were made to site V (see Figures 6 and 7) in addition to 5 one day visits. The intent of these extended trips was to observe the facility and staff cope with anticipated changes in influent quality.

The on site analyses performed at site V indicate consistent noncompliance with the effluent turbidity standard up until approximately March 29, 1980 (Table 13, Figure 8). During the visit spanning March 17-20 recommendations were made, and carried out, calling for improved maintenance of the facility. The recommendations included cleaning out of the flocculator of 3-4 in., of solids, thorough raking of the filters during backwashing and the removal from the clearwell of approximately 2 in of sand and silt. The effluent turbidity data after completion of these measures indicate compliance. The influent turbidity was subject to rapid fluctuations and levels greater than 100 ntu. During one 3-hour period the influent turbidity rose from 17 to greater than 100 ntu and the plant effluent turbidity remained less than 1 ntu. The free chlorine residual in the plant effluent was always greater than 2 mg/l and 8 out of the 10 distribution system samples had free chlorine residuals greater than 2 mg/l. No total coliforms were detected in treated water samples and the highest standard plate count was 4 per ml.

The instantaneous TTHM analyses results were all less than 27 $\mu\text{g/l}$ (Table 14). At ambient temperature and uncontrolled pH conditions, 2 day terminal TTHM values for the influent samples were 17.8 and 13.6 $\mu\text{g/l}$.

The analyses performed by the USEPA indicated compliance with all of the primary contaminant level pollutants in the treated water samples (Table 15). The secondary MCL for manganese was exceeded in 4 of the 6 treated water samples and the level of sulfate and total dissolved solids exceeded the MCL in 1 of the 6 samples. The influent water exceeded the secondary limits only for manganese.

Compliance with the effluent turbidity standard occurred at site V as a result of the operational staff's efforts. During the study the staff instituted a program of regularly measuring and recording the turbidity of the influent and effluent and the pH of the influent, effluent and in the floccu-

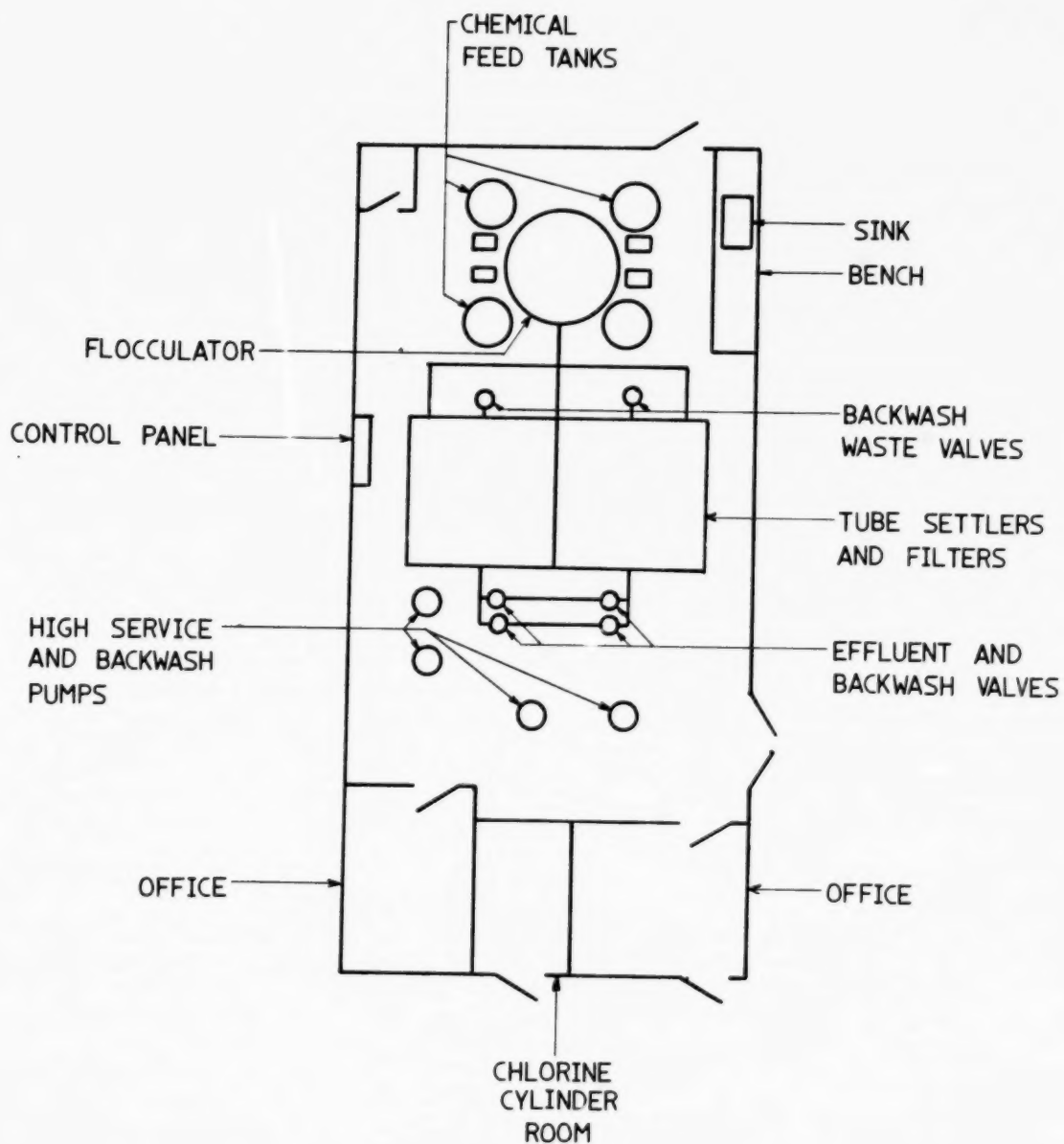


Figure 6. Site V Facility layout

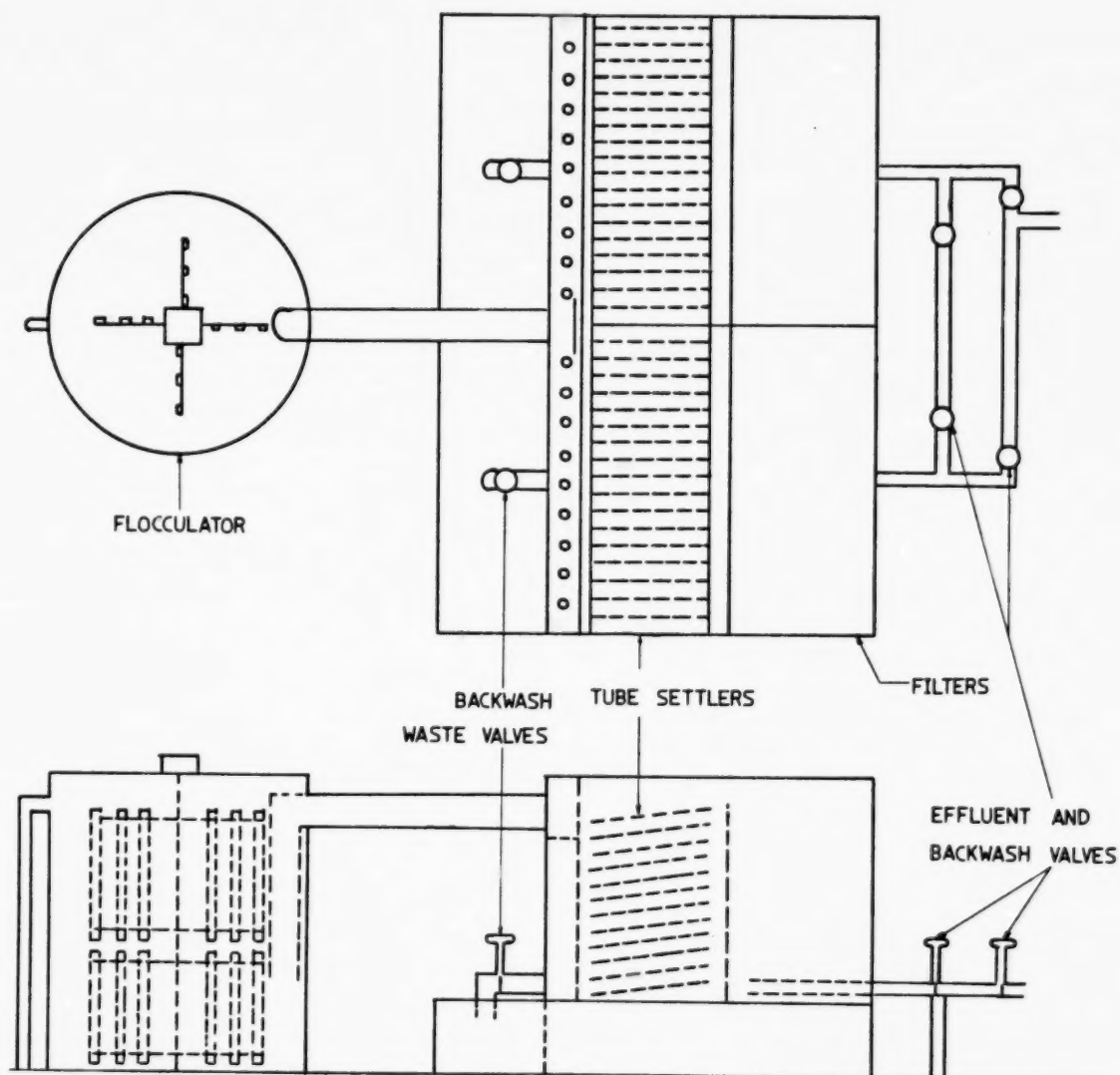


Figure 7. Site V Neptune Microfloc AQ-40 200 gpm

TABLE 13 SITE V MICROBIOLOGICAL ANALYSES AND WATER QUALITY CHARACTERISTICS

DATE	RAW Total Coliforms 100 ml	CLEARWELL EFFLUENT			1ST DISTRIBUTION			2ND DISTRIBUTION		
		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml
12/02/79	< 4	> 2.	< 1	2	> 2.	< 1	4	> 2.	< 1	< 1
1/22/80	3,600	> 2.	< 1	1	> 2.	< 1	< 1	> 2.	< 1	< 1
6/10/80	5,800	> 2.	< 1	< 1	> 2.	< 1	< 1	> 2.	< 1	< 1
11/17/80	4,200	> 2.	< 1	-	0.90	< 1	-	0.2	< 1	-
3/31/81	5,400	> 2.	< 1	< 1	> 2.	< 1	< 1	> 2.	< 1	< 1

DATE	TIME	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
12/06/79		7.5	7.7	42.	65.	150.	144.	4	1.8	
1/22/80		7.7	8.1	29.	77.	117	100.	12	2.8	
3/04/80	10:45am	-	-	-	-	-	-	-	7.2	
	11:05am	-	-	-	-	-	-	-	6.3	
	12:00n	-	-	-	-	-	-	-	15.4	
3/05/80	8:30am	-	-	-	-	-	-	35	1.5	
3/06/80	8:30am	-	-	-	-	-	-	45	2.1	
	10:30am	-	-	-	-	-	-	45	2.0	
	1:15pm	-	-	-	-	-	-	35	1.9	
3/17/80	9:30am	7.3	7.6	34	60	122	117	10	1.2	2.0
	10:55am	-	-	-	-	-	-	-	0.5	
	11:45am	-	-	-	-	-	-	-	3.0	
	4:00pm	-	-	-	-	-	-	-	5.0	

TABLE 13 (Cont.)

DATE	TIME	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
3/18/80	8:40am	6.9	7.1	30	76	108	120	82	5.7	1.5
	9:30am	-	-	-	-	-	-	> 100	-	
	9:55am	-	-	-	-	-	-	-	8.1	
	11:30am	-	-	-	-	-	-	95	8.3	
3/19/80	12:00n	-	-	-	-	-	-	-	12.0	1.8
	8:45am	7.6	-	30	-	140	-	50	7.0	
	9:25am	-	-	-	-	-	-	21	4.6	
	12:00n	-	-	-	-	-	-	13	4.6	
3/20/80	8:25am	4.6	7.5	0	40	100	90	17	0.2	
	10:00am	-	-	-	-	-	-	22	0.3	
	11:00am	-	-	-	-	-	-	17	0.3	
	9:00am	6.9	7.5	25	49	120	111	66	0.8	
3/31/80	9:20am	-	-	-	-	-	-	66	1.0	
	10:40am	-	-	-	-	-	-	59	1.5	
	12:30pm	-	-	-	-	-	-	41	1.3	
	1:30pm	-	-	-	-	-	-	35	0.9	
	2:30pm	-	-	-	-	-	-	28	1.4	
	3:30pm	-	-	-	-	-	-	31	1.7	
4/01/80	8:10am	7.3	7.3	40	58	108	106	15	1.4	> 2.
	9:45am	-	-	-	-	-	-	12	0.5	
	10:45am	-	-	-	-	-	-	13	0.5	
	8:00am	7.5	7.6	29	50	119	120	11	0.6	
4/02/80	9:00am	-	-	-	-	-	-	7	0.3	2.1
	10:00am	-	-	-	-	-	-	8	0.2	
	11:00am	-	-	-	-	-	-	8	0.1	

TABLE 13 (Cont.)

DATE	TIME	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
4/03/80	8:10am	7.3	7.6	30	43	120	118	6	0.9	> 2.
	9:00am	-	-	-	-	-	-	7	0.2	
	10:10am	-	-	-	-	-	-	6	0.1	
	11:00am	-	-	-	-	-	-	6	0.3	
4/14/80	12:00n	-	-	-	-	-	-	7	0.2	
	1:00pm	-	-	-	-	-	-	7	0.2	
	9:00am	7.3	7.5	27	49	55	68	22	0.4	
	10:00am	-	-	-	-	-	-	17	0.3	
	11:00am	-	-	-	-	-	-	17	0.4	
	11:45am	-	-	-	-	-	-	37	0.6	
	12:15pm	-	-	-	-	-	-	60	0.6	
	1:00pm	-	-	-	-	-	-	> 100	0.5	
4/15/80	1:45pm	-	-	-	-	-	-	> 100	0.8	> 2.
	3:00pm	-	-	-	-	-	-	> 100	0.5	
	8:40am	-	7.4	13	39	70	90	> 100	0.6	
	9:10am	-	-	-	-	-	-	70	0.4	
	10:00am	-	-	-	-	-	-	31	0.4	
	11:00am	-	-	-	-	-	-	32	0.4	
	12:00n	-	-	-	-	-	-	37	0.6	
	9:35am	7.9	7.6	21	45	91	101	17	0.6	
4/16/80	11:00am	-	-	-	-	-	-	15	1.7	
	12:00n	-	-	-	-	-	-	17	1.5	
	12:35pm	-	-	-	-	-	-	-	1.4	
	1:20pm	-	-	-	-	-	-	45	1.0	
4/17/80	8:30am	7.2	7.6	29	47	106	95	21	0.4	
	9:00am	-	-	-	-	-	-	11	0.3	
	10:00am	-	-	-	-	-	-	10	0.3	
	11:00pm	-	-	-	-	-	-	9	0.3	
6/10/80	7:3	6.6	6.6	40	31	134	130	2.7	1.2	> 2.
	11/17/80	6.2	8.6	48	68	206	229	1.2	1.0	
	3/31/81	7.4	7.3	28	50	119	110	3.3	0.5	

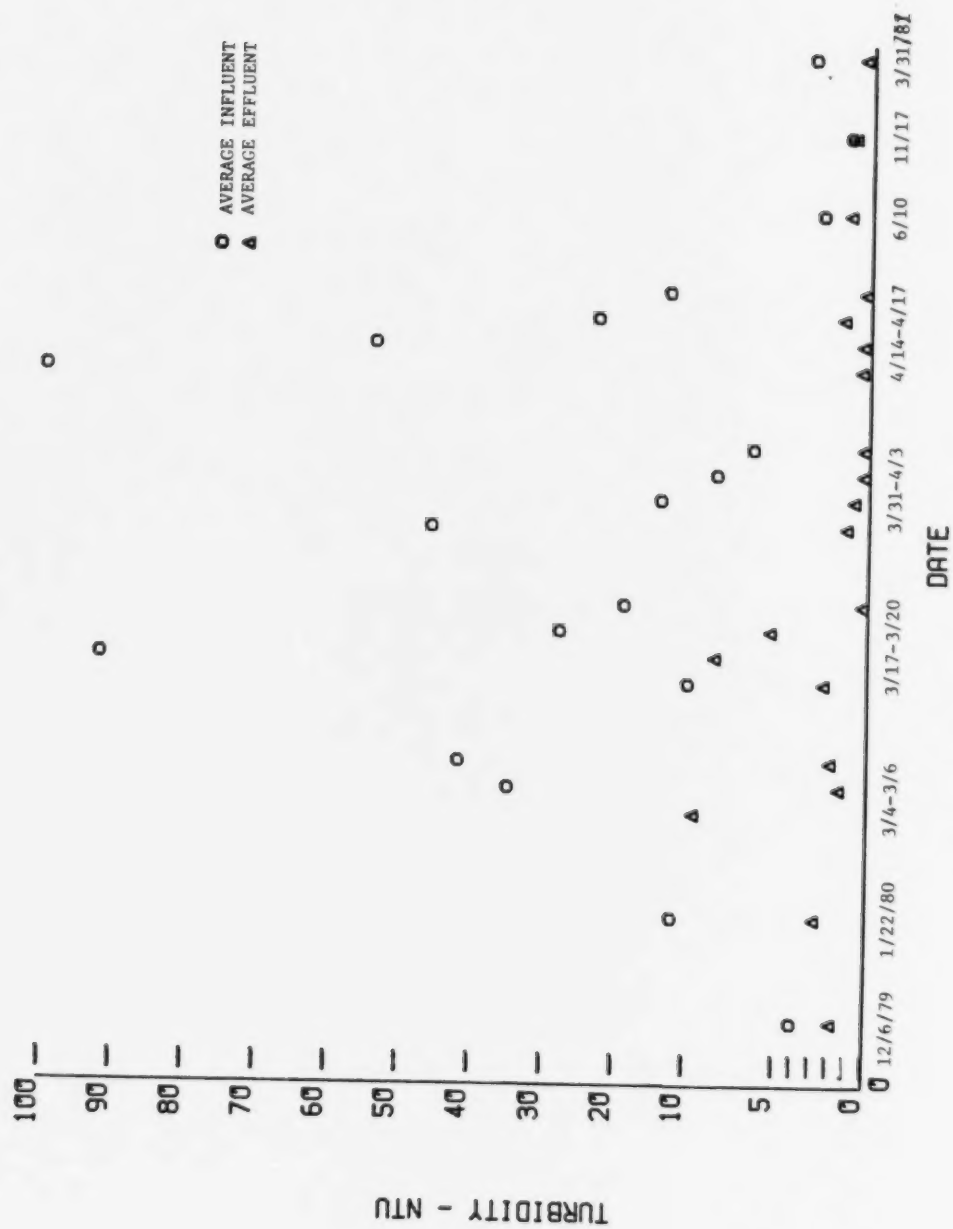


Figure 8 Site V Turbidity Removal

TABLE 14 SITE V TRIHALOMETHANE ANALYSIS

INSTANTANEOUS THM						
DATE	SAMPLE	CHCL ₃ (µg/l)	CHCL ₂ Br (µg/l)	CHCLBr ₂ (µg/l)	CHBr ₃ (µg/l)	TOTAL THM (µg/l)
06/10/80	Effl.	15.0	8.0	N.D.	N.D.	23.0
11/17/80	Effl.	3.4	1.4	N.D.	N.D.	4.8
11/17/80	2nd Distr.	8.5	8.5	7.0	N.D.	24.0
11/17/80	2nd Distr.	8.6	9.6	8.0	N.D.	26.2
11/17/80	2nd Distr.	6.7	9.6	6.9	N.D.	23.2

TERMINAL THM (2 DAY)							
DATE	SAMPLE	CHLORINE DEMAND (mg/l)	CHCL ₃ (µg/l)	CHCL ₂ Br (µg/l)	CHCLBr ₂ (µg/l)	CHBr ₃ (µg/l)	TOTAL THM (µg/l)
06/10/80	Infl.	0.3	14.6	3.2	N.D.	N.D.	17.8
06/10/80	Infl.	0.3	9.3	1.5	2.8	N.D.	13.6

N.D. - None Detected						
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TABLE 15 SITE V CHEMICAL ANALYSES PERFORMED BY USEPA (mg/L except as noted)

	FEB. 1979			JUNE 1980			NOV. 1980			MARCH 1981		
	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.
PRIMARY MCL												
ARSENIC (0.05)	-	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BARIUM (1.)	-	0.46	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
CADMIUM (0.01)	-	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
CHROMIUM (0.05)	-	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
FLUORIDE (1.4 to 2.4)	-	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
LEAD (0.05)	-	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
MERCURY (0.002)	-	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
NITRATE-N (10.)	-	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.7	0.7	0.7	0.7	0.7
SELENIUM (0.01)	-	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILVER (0.05)	-	0.04	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SECONDARY MCL												
CHLORIDE (250.)	-	-	< 10.	18.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
COLOR (15 C.U.)	-	3.	6.	3.	3.	3.	3.	2.	2.	2.	2.	2.
COPPER (1.0)	-	0.15	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
IRON (0.3)	-	0.24	0.13	< 0.1	< 0.1	< 0.1	< 0.1	0.12	< 0.1	< 0.1	< 0.1	< 0.1
MANGANESE (0.05)	-	0.31	0.49	0.62	0.19	0.12	0.12	0.15	0.11	0.03	0.03	0.03
SULFATE (250.)	-	130.	192.	220.	222.	284.	284.	93.	116.	110.	105.	105.
TOTAL DISSOLVED SOLIDS (500)	-	252.	364.	390.	407.	559.	559.	187.	236.	237.	237.	237.
ZINC (5.)	-	< 0.02	0.11	0.07	0.19	0.04	0.04	0.04	< 0.02	0.40	< 0.02	< 0.02
ALKALINITY												
CALCIUM	-	33.	42.	42.	44.	70.	70.	25.	37.	42.	37.	37.
HARDNESS	-	24.2	33.5	37.5	40.3	53.2	53.2	20.4	19.5	18.5	18.5	18.8
MAGNESIUM	-	134.	204.	212.	220.	248.	248.	114.	120.	110.	108.	108.
SODIUM (20.)*	-	18.2	23.3	23.8	24.6	29.2	29.2	13.1	13.9	12.5	12.1	12.1
SPECIFIC CONDUCTANCE (µMHOS) @ 25°C	-	17.9	28.9	31.3	30.9	71.0	71.0	8.0	24.9	33.6	22.7	22.7
	-	376.	536.	556.	576.	774.	774.	287	268.	372.	335.	335.

*The USEPA promulgated, on August 27, 1980, a sodium monitoring requirement to become effective in February 1982. While no maximum contaminant level has been set for sodium, the preamble to the amendments indicates that 20mg/l should be the goal.

lator. In addition, the maintenance measures recommended by the study were incorporated into the regular maintenance routine. These efforts enabled adequate turbidity removals from a stream source water that contained fluctuating turbidities ranging up to values higher than 100 ntu.

Site R

The site R operational staff's responsibilities included plant operation, distribution system repair and meter reading. The distribution system was frequently in need of repairs and required the greatest part of the staff's time. The operators typically started the plant in the morning and then went off to repair the distribution system or read meters. The plant was left unattended through most of its operating time. It was in operation an average of almost ten hours per day. A chart prepared by a previous operator relating influent turbidity with chemical feed pump settings was often consulted at the daily start-up of the plant. None of the three man staff was licensed, so the PSD was required to retain a consultant operator. The consultant operator visited site R approximately once per week.

Fourteen field trips, including 3 extended trips, were conducted to site R (see Figures 9 and 10). The extended trips were undertaken to observe the functioning of the treatment unit under varying influent conditions. These extended visits revealed that the treatment plant was poorly maintained. There was approximately 3 ft. of mud in the bottom of the flocculator. The banks of the tube settlers had compressed or collapsed due to the weight of built up solids that were not rinsed out in the backwash cycle. The poor performance of the flocculation and sedimentation processes resulted in excessive solids buildup in the filters. At the completion of a filter backwash cycle the backwash water was still turbid. The flocculator was cleaned out during the week of May 12, 1980. Subsequent site visits indicate this limited maintenance had little effect on turbidity removal.

The effluent turbidity ranged from 0.1 to greater than 100 ntu (Table 16). The effluent turbidity was rarely in compliance with the federal standard unless the influent turbidity was quite low. The free chlorine residual ranged from 0.0 to greater than 2 mg/l in the plant effluent and distribution system samples. On 2 different occasions distribution system samples had no free chlorine residual. No total coliforms were detected in the plant effluent or distribution system samples examined although time did not permit microbiological samples to be taken during periods of highest effluent turbidity. Total coliforms in the raw water ranged from 750 to 9,500 per 100 ml. The standard plate count ranged from less than 1 to 2,400 per ml. The THM determinations summarized in Table 17 indicate low levels of TTHM. The primary and secondary MCL analyses indicate compliance in all treated water samples with the exception of manganese in 2 samples (Table 18). The influent water exceeded the secondary limits for color, iron, and manganese.

The above data demonstrate that the site R treatment facility did not remove a sufficient amount of turbidity on most site visits. Effluent turbidity measurements of 1.5 ntu or less occurred only when the influent turbidity was less than approximately 20 ntu. The high effluent turbidity values were due to a lack of operator attention, especially insufficient maintenance on the flocculator and tube settlers. A lack of operator skill and the required

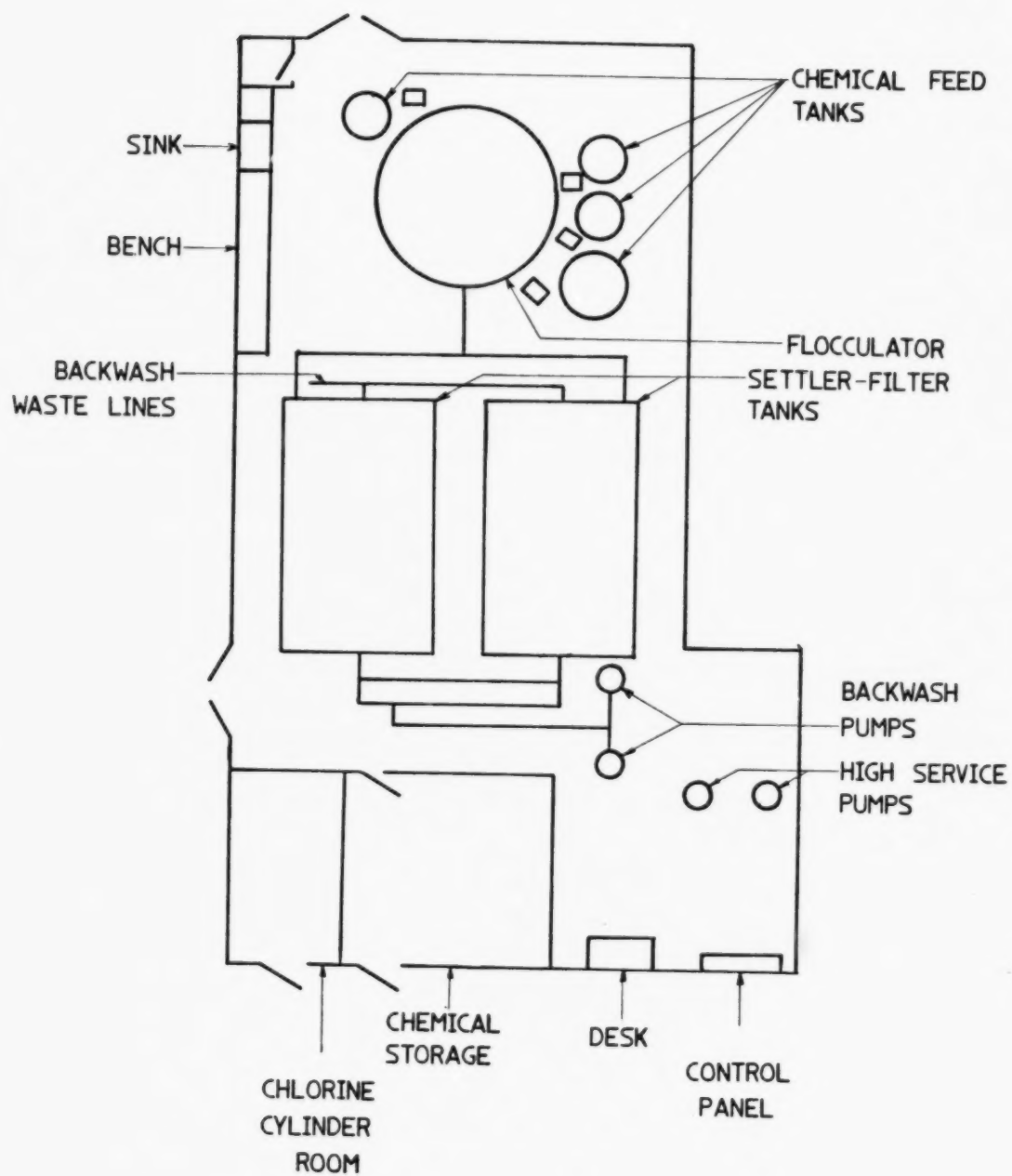


Figure 9. Site R Facility layout

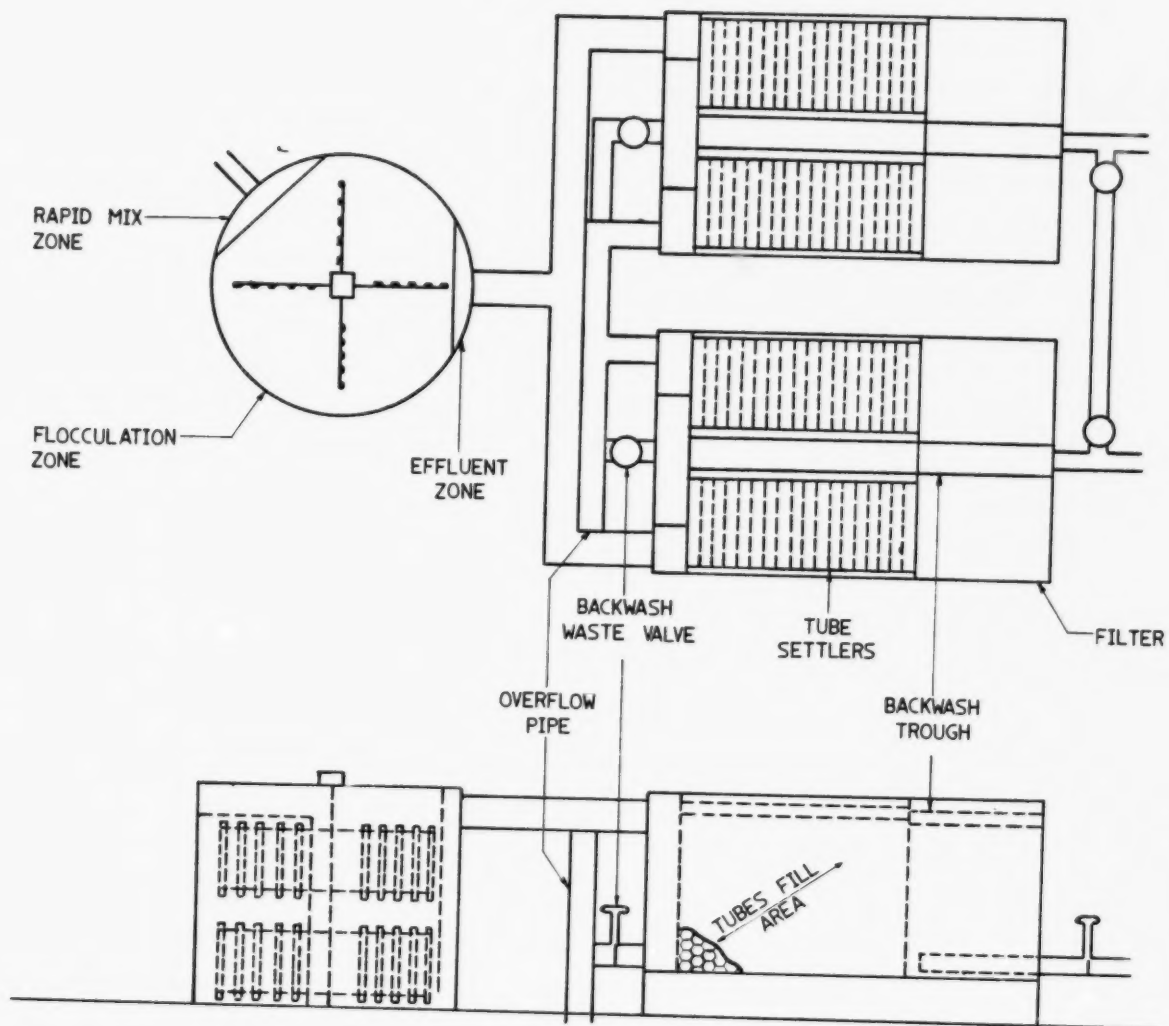


Figure 10. Site R Neptune Microfloc AQ-112 560 gpm

TABLE 16 SITE R MICROBIOLOGICAL ANALYSES AND WATER QUALITY CHARACTERISTICS

DATE	RAW Total Coliforms 100 ml	CLEANWELL EFFLUENT			1ST DISTRIBUTION			2ND DISTRIBUTION		
		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml
7/17/79	4,000	0.2	< 1	-	0.0	< 1	-	1.1	< 1	-
8/14/79	6,500	1.9	< 1	< 1	0.1	< 1	2,400	1.2	< 1	< 1
10/01/79	7,100	1.9	< 1	7	0.8	< 1	2	1.8	< 1	20
10/30/79	6,500	1.9	< 1	< 1	0.9	< 1	< 1	-	-	-
12/03/79	750	> 2.	< 1	1	> 2.	< 1	< 1	> 2.	< 1	< 1
1/23/80	5,700	0.6	< 1	5	1.6	< 1	8	0.6	< 1	2
6/09/80	9,500	2.	< 1	1	> 2.	< 1	< 1	0.0	< 1	600
11/18/80	5,700	0.2	< 1	2	> 2.	< 1	< 1	1.8	< 1	< 1
3/30/81	8,800	> 2.	< 1	3	> 2.	< 1	2	1.4	< 1	2

DATE	TIME	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
5/11/79	-	-	7.1	-	54.	-	53.	-	0.2	-
7/20/79	-	-	-	244.	32.	-	120.	39.	3.8	> 2.
8/14/79	7.1	6.8	7.4	34.	30.	148.	138.	40.	2.6	1.9
10/01/79	7.4	7.8	7.2	49.	59.	100.	94.	27.	2.4	1.9
10/30/79	7.2	8.2	7.3	43.	62.	140.	142.	6.0	1.2	1.9
12/05/79	7.3	6.8	7.2	30.	22.	112.	112.	3.8	0.1	0.6
1/23/80	7.2	6.7	-	20.	18.	104.	80.	73.	11.	0.6
2/04/80	10:30am	-	-	-	-	-	-	3.7	0.1	-
	11:15am	-	-	-	-	-	-	3.5	0.1	-
	1:00pm	-	-	-	-	-	-	3.5	0.2	-
2/05/80	6.8	6.9	7.1	48.	29.	122.	118.	3.8	0.3	> 2.
2/06/80	7.1	7.4	-	43.	52.	130.	133.	6.0	0.5	-

TABLE 16 (Cont.)

DATE	TIME	PH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
4/28/80	8:50am	7.2	8.4	11.	40.	58.	58.	> 100.	28.	2.
	10:00am	-	-	-	-	-	-	-	24.	
	11:00am	-	-	-	-	-	-	72.	22.	
	12:00n	-	-	-	-	-	-	65.	24.	
	1:00pm	-	-	-	-	-	-	64.	13.	
	2:00pm	-	-	-	-	-	-	63.	9.3	
	3:15pm	-	-	-	-	-	-	62.	7.5	
4/29/80	4:00pm	-	-	-	-	-	-	56.	13.1	1.4
	4:50pm	-	-	-	-	-	-	56.	7.0	
	8:30am	6.2	7.2	11.	35.	70.	59.	-	5.1	
	9:30am	-	-	-	-	-	-	27.	5.1	
	10:30am	-	-	-	-	-	-	26.	3.0	
	11:30am	-	-	-	-	-	-	24.	2.0	
	12:10pm	-	-	-	-	-	-	24.	1.8	
4/30/80	2:30pm	-	-	-	-	-	-	28.	1.7	
	3:30pm	-	-	-	-	-	-	20.	4.9	
	9:00am	6.8	7.6	-	40.	60.	60.	> 100.	3.7	
	-	-	-	-	-	-	-	> 100.	39.	
5/01/80	9:00am	-	-	-	-	-	-	> 100.	80.	
	10:00am	-	-	-	-	-	-	> 100.	> 100.	
	11:00am	-	-	-	-	-	-	> 100.	> 100.	
	12:00n	-	-	-	-	-	-	> 100.	> 100.	
5/12/80	9:00am	7.1	7.3	30.	50.	139.	136.	> 100.	60.	
	10:00am	-	-	-	-	-	-	> 100.	39.3	
	11:00am	-	-	-	-	-	-	> 100.	15.6	
	12:00n	-	-	-	-	-	-	-	11.	
	1:00pm	-	-	-	-	-	-	17.5	4.6	
	2:00pm	-	-	-	-	-	-	9.3	4.7	
	3:00pm	-	-	-	-	-	-	6.2	3.8	
	-	-	-	-	-	-	-	5.9	1.1	
	-	-	-	-	-	-	-	7.2	0.6	
	-	-	-	-	-	-	-	7.0	0.5	
	-	-	-	-	-	-	-	6.4	0.4	
	-	-	-	-	-	-	-	-	-	

TABLE 16 (Cont.)

DATE	TIME	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l) Clearwell Effluent
		Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	
6/02/80		7.7	7.7	48.	48.	139.	140.	4.3	0.4	2.0
6/03/80	8:50am	7.8	7.4	46.	58.	142.	140.	4.4	0.5	
	10:00am	-	-	-	-	-	-	4.6	0.3	
	11:00am	-	-	-	-	-	-	4.1	0.5	
	12:00n	-	-	-	-	-	-	3.8	0.8	
	1:00pm	-	-	-	-	-	-	3.8	1.5	
	2:05pm	-	-	-	-	-	-	3.9	1.5	
	3:05pm	-	-	-	-	-	-	3.8	1.4	
	4:00pm	-	-	-	-	-	-	4.0	1.4	
6/04/80	9:00am	7.8	7.4	45.	60.	131.	148.	10.1	2.0	
	10:00am	-	-	-	-	-	-	8.0	2.4	
	11:00am	-	-	-	-	-	-	9.5	1.9	
	12:00n	-	-	-	-	-	-	10.6	1.4	
6/09/80		7.2	7.3	20.	38.	90.	90.	19.1	1.1	> 2.
	11/18/80	7.1	7.5	47.	77.	139.	167.	64.	6.9	0.2
3/30/81		7.0	7.3	20.	51.	81.	88.	8.2	1.04	> 2.

TABLE 17 SITE R TRIHALOMETHANE ANALYSIS

INSTANTANEOUS THM						
DATE	SAMPLE	CHCl ₃ (µg/l)	CHCl ₂ Br (µg/l)	CHClBr ₂ (µg/l)	CHBr ₃ (µg/l)	TOTAL THM (µg/l)
10/30/80	Effl.	14.5	0.5	N.D.	N.D.	15.0
06/09/80	Effl.	0.5	N.D.	N.D.	N.D.	0.5
06/09/80	Effl.	4.3	N.D.	N.D.	N.D.	4.3
TERMINAL THM (2 DAY)						
DATE	SAMPLE	CHLORINE DEMAND (mg/l)	CHCl ₃ (µg/l)	CHCl ₂ Br (µg/l)	CHClBr ₂ (µg/l)	CHBr ₃ (µg/l)
06/09/80	Infl.	1.55	28.8	3.7	N.D.	N.D.
06/09/80	Infl.	0.62	64.4	13.6	1.9	N.D.
N.D. - None Detected						
						TOTAL THM (µg/l)
						32.5
						79.9

TABLE 18 SITE R CHEMICAL ANALYSES PERFORMED BY USEPA (mg/L except as noted)

PRIMARY MCL	FEB. 1979		JUNE 1980		OCT. 1980		MARCH 1981	
	INFL.	EFFL.	INFL.	EFFL.	INFL.	EFFL.	INFL.	EFFL.
ARSENIC (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BARIUM (1.)	0.49	0.2	0.37	0.2	0.2	0.2	0.2	0.2
CADMIUM (0.01)	< 0.002	< 0.002	< 0.005	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
CHROMIUM (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
FLUORIDE (1.4 to 2.4)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
LEAD (0.05)	0.096	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
MERCURY (0.002)	0.0008	0.0009	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
NITRATE-N (10.)	0.7	-	-	< 0.3	< 0.3	< 0.3	0.9	0.7
SELENIUM (0.01)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILVER (0.05)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SECONDARY MCL								
CHLORIDE (250.)	180.	-	-	< 10.	< 10.	< 10.	< 10.	< 10.
COLOR (15 C.U.)	4.	3.	3.	20.	3.	2.	2.	2.
COPPER (1.0)	1.55	0.06	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
IRON (0.3)	2.11	0.61	< 0.1	1.18	< 0.12	0.29	0.1	0.11
MANGANESE (0.05)	0.22	0.20	0.09	0.68	< 0.03	0.12	0.03	< 0.03
SULFATE (250.)	110.	76.	90.	138.	184.	78.	78.	70.
TOTAL DISSOLVED								
SOLIDS (500)	386.	156.	184.	268.	387.	158.	161.	142.
ZINC (5.)	0.23	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.20
ALKALINITY								
CALCIUM	0.	20.	29.	38.	70.	22.	20.	17.
HARDNESS	16.7	16.6	14.9	25.7	32.3	16.4	17.0	14.2
MAGNESIUM	100.	86.	88.	130.	152.	90.	92.	80.
SODIUM (20.)*	11.	11.0	10.6	14.8	16.9	9.58	9.64	9.20
SODIUM (20.)*	35.	9.	20.9	27.1	65.0	10.2	10.2	9.4
SPECIFIC CONDUCTANCE (µMHOS @ 25°C)	1459.	239.	292.	407.	586.	255.	255.	226.

*The USEPA promulgated, on August 27, 1980, a sodium monitoring requirement to become effective in February 1982. While no maximum contaminant level has been set for sodium, the preamble to the amendments indicates that 20mg/l should be the goal.

repair of the distribution system caused a low priority to be attached to the operation of the treatment plant. The source water quality was at times extremely poor with an estimated maximum influent turbidity of well over 500 ntu.

Site P

Site P (see Figures 11 and 12) employed a part-time operator since they were unable to find a qualified full-time person. The chairman of the PSD also operated the plant some of the time. The operator's responsibilities included plant operation, distribution system maintenance and meter reading. The operator was present approximately 2 hours per day although the plant operated an average of 13.7 hours per day. During the 2 hours the chemical feed solutions were replenished as necessary and the routine analyses were performed.

The effluent turbidity was greater than 1 ntu on 6 of the 9 site visits (Table 19) although the influent turbidity never exceeded 17.2 ntu. The pH of the source was always acidic, ranging from 4.5 to 5.9. The effluent pH was acidic in 7 of the 8 samples tested. The free chlorine residual in the plant effluent and distribution system samples ranged from 0.0 to greater than 2. mg/l. No total coliforms were detected in any treated water samples and the standard plate counts of the treated water samples ranged from less than 1 to 20 per ml. The source water total coliforms ranged from 2 to 1500 per 100 ml.

Effluent TTHM's were low [(22.2 and 34.5 $\mu\text{g/l}$) (Table 20)]. A distribution sample had a TTHM concentration of 214 $\mu\text{g/l}$. The primary and secondary maximum contaminant level analyses performed by USEPA indicated compliance in all the treated water samples (Table 21). The influent water exceeded only the secondary limits for manganese.

The data from site P indicate a lack of operator presence to be the cause of the turbidity standard being exceeded. The facility had a higher average daily operating time than any of the other plants studied and only had a part-time operator. The plant was typically left in an automatic mode 24 hours per day. The chemical feed lines were removed from their injectors in the influent pipe to discharge into the top of the rapid mix chamber because the injectors would occasionally clog during the long hours of unattended operation. This move negated the use of the rapid mix chamber and in line chemical mixing. The operator was never observed adjusting chemical doses to effect better coagulation and flocculation. The low effluent pH bears out the apparent lack of control of the coagulation chemicals.

Site C

The site C treatment plant was different from the others studied in that it consisted of a solids contact upflow clarifier and 2 rapid sand filters (see Figures 13 and 14). The operators maintained the pH in the solids contact unit at 6.1 and tried to keep the sludge blanket well defined and low. The sand filters had been built with rate of flow control valves but the operators installed hand controlled valves instead. The filter backwash was carried out manually rather than by a cam timer.

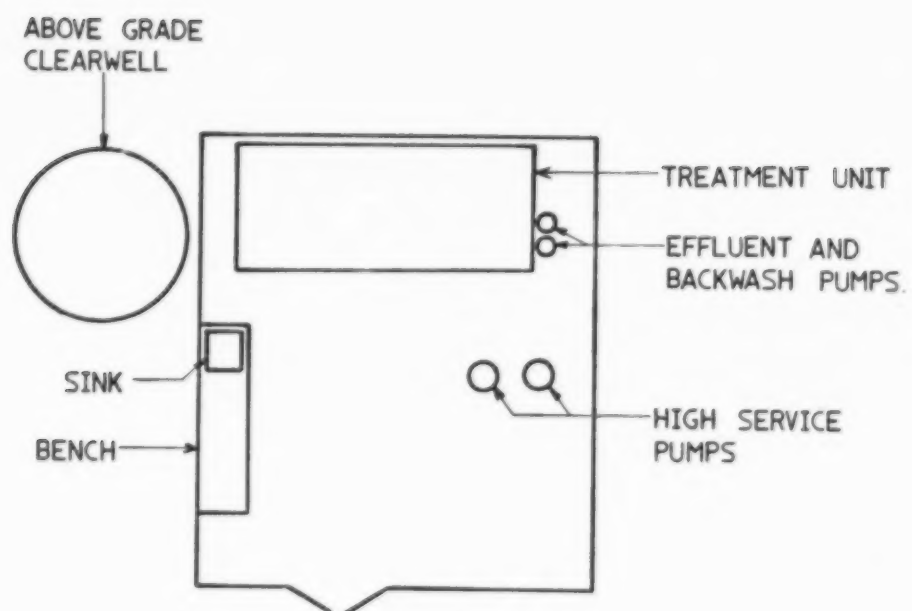


Figure 11. Site P Facility layout

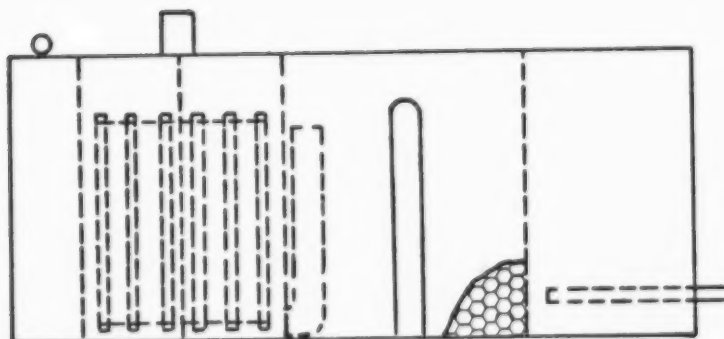
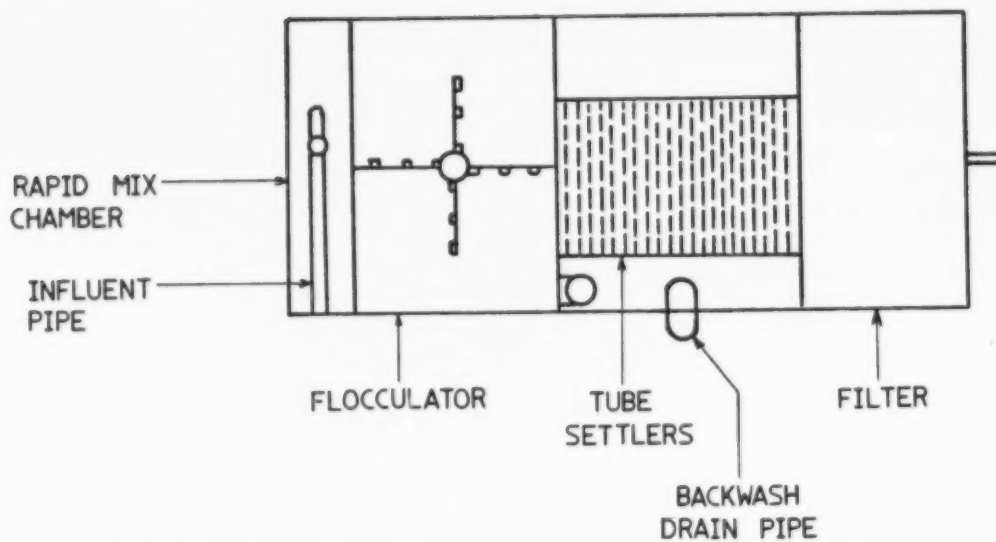


Figure 12. Site P Neptune Microfloc WB-133 100 gpm

TABLE 19 SITE P MICROBIOLOGICAL ANALYSES AND WATER QUALITY CHARACTERISTICS

DATE	RAW Total Coliforms 100 ml	CLEARWELL EFFLUENT			1ST DISTRIBUTION			2ND DISTRIBUTION		
		Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml
6/11/79	90	0.0	< 1	7	0.0	< 1	20	0.0	< 1	8
8/29/79	590	0.5	< 1	< 1	0.8	< 1	1	0.1	< 1	5
10/15/79	21	0.6	< 1	11	0.2	< 1	2	-	-	-
11/13/79	30	1.8	< 1	< 1	1.5	< 1	< 1	-	-	-
1/07/80	2	> 2.	< 1	< 1	> 2.	< 1	1	> 2.	< 1	< 1
6/23/80	470	> 2.	< 1	8	> 2.	< 1	< 1	-	-	-
10/28/80	57	1.3	< 1	-	1.5	< 1	-	-	-	-
4/13/81	1,500	> 2	< 1	-	0.63	< 1	-	0.32	< 1	-

DATE	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l)	
	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Rawwell Effluent	Clearwell Effluent
6/11/79	4.5	5.4	2.	19.	42.	45.	12.	0.8	0.0	0.0
8/03/79	4.5	6.8	2.	18.	20.	20.	4.4	2.4	0.3	0.3
8/29/79	-	6.9	6.	20.	25.	30.	-	7.0	0.5	0.5
10/15/79	-	-	1.	12.	10.	14.	3.5	1.5	0.6	0.6
11/13/79	5.9	6.9	4.	36.	22.	24.	2.0	0.1	1.8	1.8
1/07/80	5.2	8.1	0.	20.	25.	28.	1.2	0.5	> 2.	> 2.
6/23/80	5.5	6.6	9.	9.	21.	28.	15.6	9.7	> 2.	> 2.
10/28/80	5.0	6.9	2.	8.	40.	42.	3.1	2.2	1.3	1.3
4/13/81	5.1	5.2	1.	1.	19.	24.	17.2	1.9	> 2	> 2

TABLE 20 SITE P TRIHALONETHANE ANALYSIS

INSTANTANEOUS THM						
DATE	SAMPLE	CHCL ₃ (µg/l)	CHCL ₂ Br (µg/l)	CHCLBr ₂ (µg/l)	CHBr ₃ (µg/l)	TOTAL THM (µg/l)
06/23/80	Effl.	16.4	4.8	1.0	N.D.	22.2
10/28/80	Effl.	0.6	2.9	21.1	9.9	34.5
10/28/80	1st Dist.	5.1	26.4	112.	70.7	214.
TERMINAL THM (2 DAY)						
DATE	SAMPLE	CHLORINE DEMAND (mg/l)	CHCL ₃ (µg/l)	CHCL ₂ Br (µg/l)	CHCLBr ₂ (µg/l)	CHBr ₃ (µg/l)
06/23/80	Infl.	1.01	54.7	26.5	12.3	N.D.
06/23/80	Infl.	0.93	62.4	38.7	10.0	N.D.
N.D. - None Detected						
						93.5 111.

TABLE 21 SITE P CHEMICAL ANALYSES PERFORMED BY USEPA (mg/L except as noted)

PRIMARY MCL	FEB. 1979			JUNE 1980			OCT. 1980			APRIL 1981		
	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.	INFL.	EFFL.	2ND DIST.
ARSENIC (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BARIUM (1.)	0.28	0.52	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.21
CADMIUM (0.01)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
CHROMIUM (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
FLUORIDE (1.4 to 2.4)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
LEAD (0.05)	< 0.005	0.005	< 0.005	0.005	0.005	0.008	< 0.005	0.005	0.005	0.013	0.013	0.019
MERCURY (0.002)	< 0.0005	0.0008	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	< 0.0005	< 0.0005	< 0.0005
NITRATE-N (10.)	< 0.3	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
SELENIUM (0.01)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILVER (0.05)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SECONDARY MCL												
CHLORIDE (250.)	< 10.	-	40.	40.	45.	-	< 10.	< 10.	< 10.	28.	28.	20.
COLOR (15 C.U.)	3.	5.	3.	3.	3.	-	5.	3.	3.	3.	3.	3.
COPPER (1.0)	0.11	0.15	< 0.02	< 0.02	0.20	-	< 0.02	< 0.02	< 0.02	0.16	0.16	0.05
IRON (0.3)	0.28	0.57	< 0.1	0.16	0.18	-	0.35	< 0.1	< 0.1	0.19	0.19	0.18
MANGANESE (0.05)	0.11	0.19	0.20	< 0.03	< 0.03	-	0.15	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SULFATE (250.)	< 15.	< 15.	< 15.	< 15.	< 15.	-	< 15.	< 15.	< 15.	< 15.	< 15.	< 15.
TOTAL DISSOLVED SOLIDS (500)	49.	45.	113.	121.	115.	-	42.	54.	93.	75.	75.	75.
ZINC (5.)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	-	0.03	< 0.02	< 0.02	0.03	0.03	< 0.02
ALKALINITY												
CALCIUM	1.	4.	1.	5.	6.	-	1.5	1.	2.	2.	2.	2.
HARDNESS	4.9	4.4	10.1	11.5	11.5	-	4.7	6.6	10.1	10.1	8.0	8.0
MAGNESIUM	11.	20.	39.	40.	40.	-	18.	22.	34.	28.	28.	28.
SODIUM (20.)*	1.12	0.65	1.85	1.86	1.89	-	1.04	1.06	1.48	1.48	1.28	1.28
SODIUM (20.)*	3.9	3.7	38.	20.3	21.2	-	4.8	5.8	15.6	15.6	11.0	11.0
SPECIFIC CONDUCTANCE (µMHOS) @ 25°C	75.	70.	204.	218.	218.	-	75.	95.	175.	175.	133.	133.

*The USEPA promulgated, on August 27, 1980, a sodium monitoring requirement to become effective in February 1982. While no maximum contaminant level has been set for sodium, the preamble to the amendments indicates that 20mg/l should be the goal.

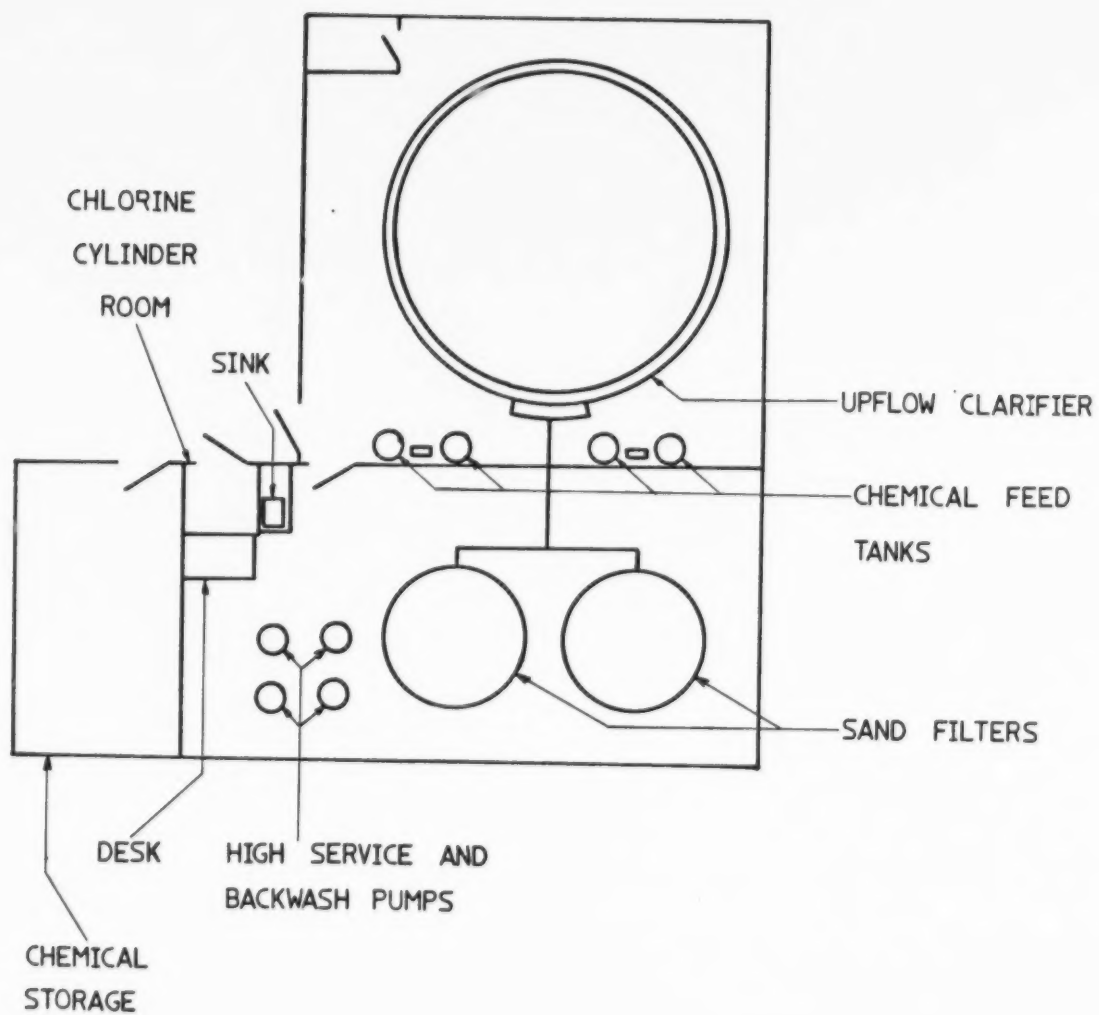


Figure 13. Site C Facility layout

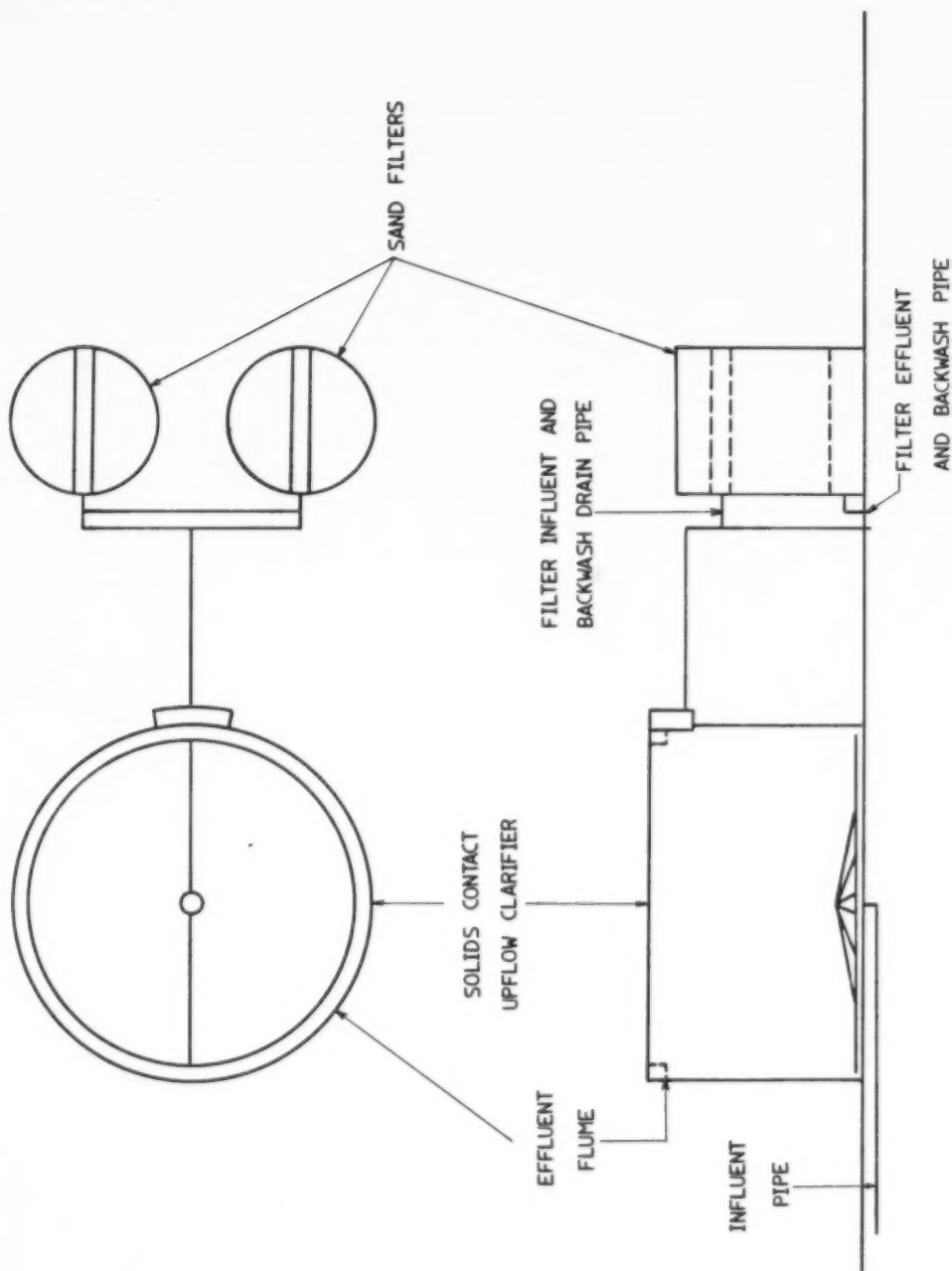


Figure 14. Site C Permitit 200 gpm

The two operators' responsibilities consisted of plant operation, distribution system maintenance, and maintenance of several package wastewater treatment plants also located in the park. The water plant operated an average of almost 5 hours per day.

The effluent data indicate that the turbidity MCL was met on all 9 site visits (Table 22). The influent turbidity ranged from 1.2 to 12.6 ntu. The operators kept a low free chlorine residual in the clearwell, between 0.1 and 1.0 mg/l, due to the small size of the distribution system. There was no free chlorine residual in 11 of the 18 distribution system samples tested and no total coliforms were detected in the treated water samples. The raw water total coliforms ranged from 25 to 1400 per 100 ml. The standard plate count ranged from less than 1 to 2,700 per ml for the effluent and distribution system samples.

Trihalomethane analyses were performed on samples taken on 3 different site visits (Table 23). The results though not consistent indicate some concentrations of THM greater than the 100 $\mu\text{g/l}$ prescribed by the USEPA for systems serving 10,000 or more population. The raw water terminal THM analyses results were 332.3 and 351.6 $\mu\text{g/l}$ reflecting the high concentration of precursor material present in the source river water.

The primary and secondary MCL analyses performed by USEPA indicate compliance in all the treated water samples (Table 24). The raw water exceeded only the secondary limits for color, iron, and manganese.

Site C successfully met all the drinking water standards on all site visits. This result was a product of sound operation and a consistently good quality influent water. The facility was monitored frequently and was never left operating unattended.

TABLE 22 SITE C MICROBIOLOGICAL ANALYSES AND WATER QUALITY CHARACTERISTICS

DATE	RAW			CLEARWELL EFFLUENT			1ST DISTRIBUTION			2ND DISTRIBUTION		
	Total Coliforms 100 ml	Free Cl mg/l	Total Coliforms 100 ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml	Free Cl mg/l	Total Coliforms 100 ml	Std. Plate ml
6/08/79	120	0.7	< 1	0.0	< 1	650	0.0	< 1	2700	0.2	< 1	100
7/31/79	77	0.1	< 1	0.0	< 1	< 1	0.0	< 1	10	0.0	< 1	56
8/27/79	390	0.2	< 1	0.1	< 1	< 1	0.1	< 1	280	0.0	< 1	35
10/16/79	66	0.7	< 1	0.1	< 1	-	0.1	< 1	-	0.0	< 1	-
11/14/79	490	0.4	< 1	0.2	< 1	-	0.2	< 1	-	0.1	< 1	-
1/07/80	640	0.6	< 1	0.1	< 1	< 1	0.1	< 1	5	0.0	< 1	2000
6/23/80	25	1.0	< 1	0.3	< 1	8	0.3	< 1	< 1	0.0	< 1	2
10/27/80	1400	0.5	< 1	0.0	< 1	< 1	0.0	< 1	150	0.0	< 1	1
4/14/81	260	0.2	< 1	0.0	< 1	-	0.0	< 1	-	0.0	< 1	-

DATE	pH		ALKALINITY (mg/l as CaCO ₃)		HARDNESS (mg/l as CaCO ₃)		TURBIDITY (ntu)		Cl (mg/l)	
	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent	Raw	Clearwell Effluent
6/08/79	6.8	6.6	20.	47.	28.	23.	8.5	0.3	0.7	0.7
7/31/79	6.2	6.6	22.	50.	30.	26.	6.2	0.2	0.1	0.1
8/27/79	6.4	7.0	18.	62.	24.	21.	1.2	0.3	0.2	0.2
10/16/79	-	-	12.	72.	22.	20.	1.6	0.1	0.7	0.7
11/14/79	6.6	9.3	18.	80.	29.	28.	2.2	0.1	0.4	0.4
1/07/80	6.5	7.0	20.	50.	30.	30.	4.0	0.1	0.6	0.6
6/3/80	6.2	8.9	19.	88.	29.	22.	12.6	0.7	1.0	1.0
10/27/80	7.2	8.2	18.	81.	31.	27.	5.2	0.2	0.6	0.6
4/14/81	6.3	7.2	10.	39.	23.	20.	2.2	0.2	0.2	0.2

TABLE 23 SITE C TRIHALOMETHANE ANALYSIS

INSTANTANEOUS THM						
DATE	SAMPLE	CHCl ₃ (µg/l)	CHCl ₂ Br (µg/l)	CHClBr ₂ (µg/l)	CHBr ₃ (µg/l)	TOTAL THM (µg/l)
10/16/79	Effl.	112.	1.3	N.D.	N.D.	113.
6/23/80	Effl.	0.06	N.D.	N.D.	N.D.	0.1
10/27/80	Effl.	77.0	23.7	N.D.	N.D.	101.
10/27/80	1st Dist.	3.3	13.0	N.D.	N.D.	16.3
10/27/80	2nd Dist.	266.	10.3	N.D.	N.D.	276.
TERMINAL THM (2 DAY)						
DATE	SAMPLE	CHLORINE DEMAND (mg/l)	CHCl ₃ (µg/l)	CHCl ₂ Br (µg/l)	CHClBr ₂ (µg/l)	TOTAL THM (µg/l)
6/23/80	Inf1.	4.4	326.	4.3	2.0	332.
6/23/80	Inf1.	4.3	340.	11.6	N.D.	352.

N.D. - None Detected

TABLE 24 SITE C CHEMICAL ANALYSES PERFORMED BY USEPA (mg/L except as noted)

PRIMARY MCL	FEB. 1979			JUNE 1980			OCT. 1980			APRIL 1981		
	INFL.	EFFL.	1ST DIST.	INFL.	EFFL.	1ST DIST.	INFL.	EFFL.	1ST DIST.	INFL.	EFFL.	1ST DIST.
ARSENIC (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
BARIUM (1.)	0.27	< 0.2	< 0.20	< 0.2	< 0.20	< 0.20	< 0.2	< 0.20	< 0.2	< 0.2	< 0.2	< 0.2
CADMIUM (0.01)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
CHROMIUM (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
FLUORIDE (1.4 to 2.4)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
LEAD (0.05)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
MERCURY (0.002)	0.0005	0.0013	0.0012	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
NITRATE-N (10.)	< 0.3	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
SELENIUM (0.01)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILVER (0.05)	< 0.03	0.04	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SECONDARY MCL												
CHLORIDE (250.)	< 10.	-	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
COLOR (15 C.U.)	18.	25.	40.	3.	3.	3.	3.	3.	3.	3.	3.	3.
COPPER (1.0)	0.04	0.12	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
IRON (0.3)	0.22	1.06	0.52	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
MANGANESE (0.05)	0.07	0.20	0.10	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SULFATE (250.)	< 15.	< 15.	15.	47.	44.	43.	43.	29.	28.	29.	29.	29.
TOTAL DISSOLVED SOLIDS (500)	55.	40.	60.	174.	172.	179.	179.	35.	104.	104.	116.	116.
ZINC (5.)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
ALKALINITY												
CALCIUM	6.	17.	15.	78.	80.	92.	92.	7.	46	46	59.	59.
HARDNESS	4.6	6.3	10.	8.0	9.9	10.8	10.8	5.7	6.0	7.9	13.5	13.5
MAGNESIUM	16.	21.	30.	28.	32.	34.	34.	16.	20.	24	32.	32.
SODIUM (20.)*	0.49	0.66	1.10	1.16	0.65	0.60	0.60	0.69	0.68	0.60	0.68	0.68
SODIUM (20.)*	1.	1.	1.9	53.5	49.5	53.0	53.0	1.2	31.	31.4	34.0	34.0
SPECIFIC CONDUCTANCE (µMHOS) @25°C	39.	52.	78.	294.	287.	302.	302.	49.	175.	189	211.	211.

*The USEPA promulgated, on August 27, 1980, a sodium monitoring requirement to become effective in February 1982. While no maximum contaminant level has been set for sodium, the preamble to the amendments indicates that 20mg/l should be the goal.

SECTION 7

SUMMARY

Six water treatment facilities selected for field research had varied success in their turbidity removals. Plant C met the turbidity requirement of 1 mtu on all site visits. Two other facilities (sites W and T) met the turbidity standard on nearly all occasions: plant W exceeded the limit once, and plant T exceeded it twice. These three facilities had low turbidity sources (1.2 to 29.7 ntu) and quality operators.

The other three participating plants (V, R and P) met the turbidity standard on fewer than half of the visits made to them. The difficulties in performance involved the variability and quality of the source, the short detention times inherent in the design of the treatment units, and the lack of skilled operators with sufficient time to devote to treatment. The Site V data appear to indicate improvement. The first eight daily values obtained at this site (encompassing a 4 month period) show noncompliance with the standard. Daily average turbidities for the last 11 sampling days (encompassing an 8 month period) indicate compliance with the 1-ntu standard, although some individual values exceeded that limit. Improved operational methods and some needed maintenance may be partially responsible for this better performance. Difficulties in turbidity removal at Site R were largely caused by the high and variable turbidity (3.5 to >100 ntu) of the source water and the staff's outside responsibilities, which required too much of their time. The influent turbidity data of Site P are consistently low (17.2 ntu maximum), indicating a treatable source. A lack of operator attention because of employment of a part-time operator is responsible for that site's noncompliance.

The treated water total coliform determinations from all 6 plants showed no total coliforms, with the exception of a distribution system sample taken at a residence. Total coliform determinations on raw water samples from the six water treatment plants varied up to 10,000 total coliforms per 100 ml. Two of the three facilities using river sources had the highest total coliform densities. The densities of total coliforms for the source rivers of these two plants were typically between 1,000 and 10,000/100 ml. The plants using impoundments for their source had raw water total coliform densities approximately one order of magnitude less than this range.

The treated water standard plate counts for all six facilities were low. Thirty percent of the samples had counts that were 1/ml or lower. Sixty-eight percent of the samples showed densities of 10/ml or lower. The highest standard plate count was 2700/ml.

The low standard plate counts and the absence of total coliforms in the treated water examined indicates that all six water treatment facilities

produced adequately disinfected water.

The analyses performed by the USEPA Drinking Water Research Division for the primary and secondary maximum contaminant level pollutants show that all primary regulations were met in all influent and effluent samples. Five effluent samples had manganese concentrations greater than the secondary maximum contaminant level prescribed by the USEPA. Also, two treated water samples exceeded the iron concentration recommended as a secondary maximum contaminant level. The results of the effluent and distribution system analyses revealed that 15 of 18 treated water samples exceeded 20 mg/l sodium.

Note that the operators of these facilities were not trying to control sodium, manganese, or iron at the time these samples were collected. The major concerns for the operators were turbidity removal and adequate disinfection.

Four of the six plants studied had at least one treated water instantaneous trihalomethane (THM) sample with a total THM concentration greater than 0.10 mg/l. The small size of these water systems precludes them from having to comply with any present THM regulations. The point of chlorination and often the large free chlorine residuals (>2. mg/l) detected in the treated water contribute to these levels of THM. All six of the plants were originally equipped with pre- and post-chlorination capabilities, but during the study, all of the plants practiced prechlorination that would contribute to high THM.

The three facilities, sites C, T, and W, that were most successful had competent operational staffs who devoted sufficient time to water treatment. These staffs all had knowledge of water treatment or great familiarity with their respective plant and dedication to their work. These staffs were characterized by frequent monitoring of the influent and effluent quality. Improvement of the water quality at site V came from increased maintenance and more frequent sampling of water through the plant. The staff at site R lacked adequate knowledge of and time to devote to water treatment. Distribution system maintenance requirements kept this staff from properly maintaining and monitoring their plant. The small percentage of time spent by the operators at site P resulted in poor effluent quality even though the influent turbidity was quite low.

Four of the plants studied had consistent source turbidities. Three of these were the result of using surface impoundments. Three of the 4 sites with uniform quality source waters produced effluent that consistently met the effluent turbidity standard. Although the source water at site P was a reservoir and the influent turbidity was not observed to be above 20 ntu, inadequate operation at this plant resulted in an effluent frequently above 1 ntu. The stream source quality at site V was variable and at times greater than 100 ntu. The average 6 hours of operation per day at site V allowed the staff to avoid some periods of highest turbidity. The site R stream source had turbidity peaks, greatly in excess of 100 ntu, that according to product literature and a manufacturer's representative could not be adequately treated at the design capacity of the treatment unit. Sites V and R caused the state health department's engineers to state that they will be reluctant to approve plans for a similarly designed unit to be installed on a highly variable stream source in the future.

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